ATLAS
OF
EMISSION SPECTRA
OF MOST OF THE ELEMENTS

PREPARED FROM PHOTOGRAPHS WITH EXPLANATORY TEXT

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Preface.

Although there exist numerous more or less modern charts of spectra, prepared by Crew, Demarçay, Eder and Valenta, Exner and Haschek, Higgs, Kayser and Runge, Rowland and others, there has hitherto been a lack of a unified atlas, embracing all elements and covering the whole spectrum, executed with the best modern means. It is hoped that the present work will meet this want in the otherwise rich spectroscopic literature. Twenty-eight charts are presented, containing, with a few exceptions, the spectra of all elements in heliographic reproduction, prepared, without retouching or alteration of any sort, from photographs taken by us with a small Rowland grating. There are lacking only the spectra of Eu, Ga, Ge, Kr, Ne, Ra, Sc, Ta, Tm, X, of which the samples obtainable were either not pure enough or in insufficient quantity. For the production of the other spectra, preparations of the substances, in some cases very valuable, were placed at our disposal through the kindness of Messrs. Eberhard, Heusler, Kayser, Muthmann, Rimbach, and we gladly take this opportunity to express our hearty thanks for this assistance.

With the relatively small scale which it was necessary to use to give the charts the best form for practical use, the preparation of the charts and the placing of the scale offered great difficulties. The technical processes do not provide for the reproduction of such fine detail, and one familiar with these matters need not be told that the charts fall far short of the detail given in the orginal photograhs. Still, the resolution obtained is quite sufficient even for spectra with many lines. As a rule, the reproductions show all lines separated which have an interval of 0.8 A = 0.08 $\mu\mu$, and this corresponds closely with the accuracy of reading possible with the scale. The latter was ruled with a dividing engine on each spectrum separately and then reproduced with it.

In view of the numerous recent investigations on the variability of spectra, we have taken especial care to obtain the spectrum of each element under as diverse conditions as possible. A glance at the charts shows how the appearance of the spectrum of one and the same element may change if the luminosity is due to different conditions, and the sort of difficulties which would arise if one tried, for example, to identify spark spectra from charts of arc spectra or vice versa. We have, however, in our variation of conditions taken account of the apparatus usually available in physical and chemical laboratories, and used only methods which can be closely followed by other observers.

The varying sensitiveness of the photographic plate for different colors, which a series of experiments did not enable us to overcome, united with the superposed orders in grating spectra, made it impossible to photograph the whole spectrum at once and forced us to divide it into two parts. The one part presents the visible spectrum, the other the part of greatest photographic activity. The first named region is presented much more extensively than has been the case in previous charts, and we hope thereby to arouse an interest which will result in more attention being paid in the future to the less refrangible part of the spectrum, which during the rapid progress of photographic methods has been greatly neglected.

At both ends of the spectrum, below $\lambda = 240$ and above $\lambda = 650$, the sensitiveness of the plate decreases so rapidly that considerably longer exposures are required; and one cannot take both the limiting region and the more actinic part on the same plate with justice to both. We have therefore contented ourselves with a reproduction of only the strongest lines outside of the sensitive region. This detracts little from the usefulness of the charts, however, as the most important part in every spectrum lies between the limits named above.

If in any spectrum lines were lacking in one of the two regions usually photographed, or were at any rate only few and weak, this half was left out and replaced by another spectrum which for any reason was considered important.

It may be mentioned here that among the spectra presented in the charts there are a large number which are either wholly or in part reproduced for the first time. As examples may be named B, As, the rare earths, the platinum elements, P, J, Se and others.

In the descriptive portion of the text we have usually mentioned only those features which are actually to be seen *in the charts*, either with the unaided eye or with a lens, and not such as are visible only on the original photographs. We have tried, while making the descriptions brief, to include all information necessary for the most effective use of the charts. Complete tables of wave-lenghts as well as all references to literature have been omitted, since these would make the text too long, and besides would be rendered superfluous by the fifth volume of H. Kayser's Handbuch der Spectroscopie, which will present all such matter in complete form.

We present therefore for each element only a selected list of lines which are characteristic or easily found, with their wave-lengths in whole Angström units, by the aid of which it is usually easy to identify the spectrum or find weaker lines of the same element. In the preparation of this part of the text we have consulted all of the special literature, so far as it was available. Special use has been made of the two volumes of wave-length tables by **Exner** and **Haschek***) In the less refrangible part of the spectrum, for which there are no corresponding tables, a complete identification of the lines was not always possible. Numerous differences from the previous assignments of lines to elements, which the experienced observer will notice, are justified by the photographs themselves.

Finally, we append a chapter of spectroscopic notes which will perhaps serve as an introduction to the subject sufficient for the purpose of those who wish to use these charts in the laboratory.

The charts were for the most part prepared by us together in the Physical Institute of the University of Bonn, the facilities of which were most kindly placed at our disposal by the Director, Professor H. **Kayser**. After the departure of one of us (**Hagenbach**) from Bonn, we took pains to preserve the unified character of the work through frequent consultations.

The publication of the atlas was aided by a grant from the Königliche Preußische Akademie der Wissenschaften, for which we wish to express our thanks. We have been able only to a limited degree to comply with the wishes of the Akademie in regard to the arrangement of the charts, as the preparation of these had already proceeded too far.

During the printing of this atlas, the collected spectroscopic works of **Eder** and **Valenta****) appeared; and these, with their most excellent heliogravures, may to some extent serve a similar purpose as the charts here presented. While the photographs of **Eder** and **Valenta** have the advantage of greater dispersion and preparation under especially favorable conditions, we hope that this atlas, through its uniform treatment of all elements may find a place beside those works devoted more to specialized study, and so be a useful aid to physicist, chemist and astronomer.

Our hearty thanks are due to the publisher, who showed the greatest patience and willingness in complying with all of our wishes.

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*) F. **Exner** and E. **Haschek**, Wellenlängentabellen auf Grund der ultravioletten Funkenspektren der Elemente, II Teile, Leipzig 1902. — id. auf Grund der ultravioletten Bogenspektren der Elemente, II Teile, Leipzig 1904. For references to the numerous special articles the reader is referred to **Kayser**'s Handbuch.

) J. M. **Eder and E. **Valenta**, Beiträge zur Photochemie und Spektralanalyse, Halle 1904. Will be referred to henceforth as "Beiträge".

Aachen and Bonn, November 1904.

A. Hagenbach. H. Konen.

Translator's Note.

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At the desire of the authors and publisher, who wished to make the Atlas available as a work of general reference for students, many of whom might not have a command of German, I have prepared this English edition of the text. The translation was made from the proof-sheets of the German edition, and the changes by the translator have been of a minor nature. In the descriptions of spectra, the wave-lengths have been checked as far as possible by the original tables and it is hoped that few errors will be found therein.

Berlin, February 1905.

A. S. King.

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Directions for use of charts.

Abbreviations. In the text the following abbreviations will be used.

Symbols of elements	see table on page 7.
wave-length	λ
Ångström unit	A
millionth-millimeter	μμ
spark	sp
flame	fla
vacuum tube	V
self-induction	S. I.
capacity	C.
doubled	d
self-reversed	r
diffuse	dif
broadened	br
component	comp
number as member of series	n

Preparation of Charts. The charts presented are heliographic reproductions of photographs which were made with the aid of two Rowland concave gratings, each of 1 m radius and 20000 lines per inch (= 2,54 cm). One of the gratings had a ruled space 9 cm broad and was used chiefly for the region of shorter wave-length. The other had a breadth of 5 cm and was used to photograph the less refrangible part of the spectrum. Both gratings belong to the Physical Institute of the University of Bonn and are in regular use there. The manner of photographing differed according to the requirements of each spectrum, and the details will be found in the exploratory notes for each spectrum and in the spectroscopic notes. The mounting of the first grating was fixed, the other was mounted according to Rowland's scheme.

Arrangement of Spectra. The order in which the spectra are placed is in general that of the natural system for the elements. Frequent deviations from this seemed, however, to be justified by the analogies existing between many spectra and also on account of some impurities being common to the members of a certain group. Spectra substituted for the missing parts of other spectra are of course out of their natural place in the arrangement.

The spectrum given by a concave grating mounted in the usual way is "normal", i. e. the distance apart of two lines or colors in a spectrum is always proportional to the difference in wave-length between them. The scale expresses this by having printed numbers at intervals of 10 $\mu\mu$ ($\mu\mu$ = millionth-millimeter); so that the difference between two scale divisions indicates a difference in wave-length of 1 $\mu\mu$. Estimating tenths of each scale-unit then gives the wave-length in 0,1 $\mu\mu$ or Ångström units. These units (A), as four figure numbers, are used as wave-length units throughout the text. For elements having known regularities in the spectrum, the wave-length tables are arranged in order of decreasing wave-length, on account of the series lines; while with other elements the tables follow the reversed order, according to the usage of the Astrophysical Journal. In designating groups of lines, or in other cases where no confusion can arise, three-figured numbers are frequently used. (See below under "wave-lengths".)

Colors and wave-lengths. For identifying wave-lengths with color or vice versa, the following scale given by Listing may be used:

Above 7 230 = infra-red
7 230 to 6 470 = red
6 470 „ 5 850 = orange
5 850 „ 5 750 = yellow
5 750 „ 4 920 = green
4 920 „ 4 550 = blue
4 550 „ 4 240 = indigo
4 240 „ 3 970 = violet
below 3 970 = ultra-violet.

Division of spectra. All spectra are divided in the photographs into two parts, in each of which the greater wave-lengths are placed to the right. The right half as a rule gives the visible, the left half the invisible part of the spectrum. The two parts overlap, but a glance at the wave-lengths will in all cases make the arrangement clear.

Comparison with prismatic spectrum. If a prismatic spectrum is compared with one of the photographs here given, it must be remembered that the dispersion given by the prism is not uniform, as with the grating, but increases from the red toward the blue. The lines in the red of the prismatic spectrum will therefore lie nearer together than they appear on the chart.

Numbering. The spectra as well as the charts are numbered consecutively. As each chart contains 10 spectra, the numbers of the two halves of a spectrum differ by 10 (e. g. Erbium spark 161, 171). It is also evident that each number indicates at the same time the chart in which the photograph occurs (e. g. 166 in chart 17, 201 in chart 21 etc.), the number of the chart being the number of the ten to which the spectrum number belongs. Also, the less refrangible halves of the spectra are always contained in charts having even numbers.

Use of a lens. In a close examination of a photograph, when seeking lines in many-lined spectra or reading off wave-lengths, a lens magnifying five to eight times will be found helpful. When the use of such a lens is especially necessary, this is indicated by the word "lens" in the description.

Wave-lengths. If a wave-length accurate to ± 1 A. is sufficient, it may be read direct from the scale. There is, however, in many cases a small correction to be made to the value so found. This correction is given in the description of that spectrum. At the same time, the values to four figures of the strongest or most characteristic lines of each element are accurately given, so that no chance for error remains. If more accurate values of wave-lengths are desired, reference must be made either to the original publications of wave-length tables or to one of the text-books on spectrum analysis. Among the most useful modern works of this sort may be mentioned the following:

F. Exner and E. Haschek, Wellenlängentabellen auf Grund der ultravioletten Funken- und Bogenspektren der Elemente. Leipzig 1902 and 1904, in 4 parts. F. Deuticke. These contain lines to λ 4700, with accuracy of about ± 0,01 A.

W. M. Watts, Index of Spectra. 2^{d} Ed. Manchester 1889, with appendices.

W. M. Watts, An introduction to the study of spectrum analysis. London 1904. Longmans Green and Co. Contains five-figured values.

H. Landolt and R. Börnstein, Physikalisch-chemische Tabellen. 2^{d} Ed. Berlin 1894. J. Springer.

J. Landauer, Article "Spectralanalyse" in "Neues Handwörterbuch der Chemie", by Fehling-Hell. Also published in book form, English translation by Tingle, John Wiley and Sons, New York 1898. Gives wave-lengths to five or six figures.

For complete bibliography and for more specialized study:

H. Kayser, Handbuch der Spektroskopie, Bd. I, II and following volumes. Leipzig 1900 und 1902. S. Hirzel.

When other than very weak lines are concerned, one may take the value from the atlas and look for this value in a more complete table, either for the single element or in a table containing the wave-lengths of all elements arranged according to increasing wave-length. The line is thus easily located and its accurate wave-length found.

Working in reverse order, one can look for a line in the atlas corresponding to a number in a table.

Example. We find a line in Chart 17, No. 167 (Molybdenum arc) whose wave-length the scale gives approximately as 3798. In the description on p. 34 no correction appears for the wave length, and 3798 is given as one of the strongest Mo lines. Turning now to EXNER and HASCHEK's "Bogenspektren", we find in the "Haupttabelle" a strong Mo line at 3798. This is evidently the line sought for, and its exact wave-length is given as 3798.41.

Let a further example be taken at random. In chart 21, No. 203 we read off all lines between 35 and 37 and find 3500, 3516, 3529, 3539, 3540, 3571, 3590, 3593, 3597, 3701. Adding the correction (—1) for this spectrum we have

3499, 3515, 3528, 3538, 3539, 3570, 3589, 3591, 3596, 3700.

In KAYSER's table of Ruthenium lines*) we find the following (intensities are in parentheses):

3499.1 (10), 3514.6 (4), 3528.8 (2)?, 3538.1 (3), 3539.4 (d), 3570.7 (2), 3589.4 (4), 3593.2 (4), 3596.3 (5), 3599.9 (4).

The „Haupttabelle" of EXNER and HASCHEK gives

3499.1 (50), 3514.7 (3), 3528.8 (5), 3538.1 (5), 3539.4 (d), 3570.7 (8), 3589.4 (5), 3593.2 (20), 3596.3 (20), 3599.9 (5).

Allowing for the different estimates of intensity, it is seen that all of the stronger Ruthenium lines are provided for and that the difference is never greater than an Ångström unit, usually much less.

Again, suppose it be desired to locate the line 3798 in the spark spectrum of Mo (chart 17, No. 168). A line appears at 3800 by the scale. The description gives as correction — 2, so we have the line sought.

Impurities. Most spectra show lines belonging to foreign elements or to compounds. The most prominent impurities are mentioned in the remarks introductory to the descriptions: others are given under the descriptions of the seperate spectra. Certain impurities are easy to recognize and can hardly lead to mistakes. Such are the cyanogen bands, appearing in almost all arc and spark spectra, the lines of calcium and sodium, the carbon lines and those of nitrogen. Other impurities are more disturbing, and with some of the rare elements it may even happen that almost any impurity may give lines stronger than those of the element itself. In such a case, the description contains a list of lines easily found which belong to the element itself, as well as a note of the impurities present and the places where a confusion might occur.

Lines of unknown origin, not mentioned in the text, may usually be identified with the help of EXNER and HASCHEK's tables, at least in the ultra-violet part, and often also by ROWLAND's tables of solar lines, the intensity of lines and conditions of production being taken into account.

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*) Astrophys. Journ. 7, p. 109, 1898.

Example. On chart 15, No. 150 let a line be located at approximately 4078 whose origin is desired. We find in the "Haupttabelle" for arc spectra of Exner and Haschek a strong Y line at 4077.54. The elements Ru, La, Sr, Hg, also having lines in this region, are improbable. In the text Y is given as an impurity. We test the matter further with other strong Y lines, as 3780, 3774, 4103, 4178, which are found on page 39 of the tables. They are also present, so that it is probable that the line in question is indeed 4078*).

Comparison with visual observations. (1) Unless the spectrum is very rich in lines, the lines and line-groups seen with the eye are usually easily recognized on the chart by merely noting the color and taking the approximate wave-length from the table on page 2. (2) In cases where this method does not suffice, if the spectroscope used has a scale, this should be calibrated to read roughly in wave-lengths by means of the spectra of the alkalis or others with few lines. This may be done quickly with the aid of the atlas. Then to compare an observed spectrum with a chart, one reads the approximate wave-length of a characteristic group of lines from the spectroscope scale and finds the corresponding place on the chart. (3) If the spectroscope has no scale, a comparison prism may be used (or if this is not available, a piece of mirror), by which the light from a known source is thrown on the slit at the same time with the light to be examined. The comparison of the known with the unknown spectrum then gives the desired readings. (4) Lastly, one may use certain oft-recurring impurity lines to locate the corresponding places in spectroscope field and chart. In vacuum tube spectra the red hydrogen line ($\lambda = 6563$) appears very easily. In the spark without self-induction the green air lines at 500 $\mu\mu$ or the blue group at 463 are easily recognized. In the carbon arc the sodium lines at 589, almost always present, or the cyanogen band at 4216 may be used in the same way. In the Bunsen or other flames, one may use either the Na-lines at 589 (either present or easily produced) or the green carbon band at λ 5164, the latter being obtained by pointing the spectroscope at the inner, luminous cone of the flame. As soon as two corresponding places in the spectra are found, all parts of both spectra may be easily brought to coincidence by working from these places in both directions.

Examples. (1) We wish, for example, to compare the spectrum given by an Arons lamp with the reproductions No. 63 and 73 of charts 7 and 8. As the observations are made with the eye, we choose No. 73 of chart 8 (see p. 3). A green line is the strongest in the lamp spectrum. From the scale on p. 2 the corresponding region of the spectrum is 492—575, from which the chart gives the line at 546 as the one sought. We now see at once that the two lines at 577 and 579 are the two yellow and that at 446 the indigo line of mercury. — (2) It is desired to compare the band spectrum of sulphur

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*) If one wishes to be quite certain, he must of course seek out *all* of the stronger Y lines and make the opposite test for the presence of other possible elements. In compiling the descriptions of the charts the original negatives were used for this purpose.

with No. 255 of chart 26, and the spectroscope has a scale. To calibrate this scale, we observe the flame spectra of Li, Na, K, Rb and perhaps the spectrum of hydrogen. The wave-lengths are given by charts 1, 2, 28. We now lay off the readings of spectroscope scale as abscissae, the wave-lengths as ordinates, and draw a curve through the points so obtained. The spectroscope shows the head of a green band of sulphur for which the scale reads 76. The ordinate of our curve corresponding to 76 gives $\lambda = 544$. We have then the head at 542 before us on No. 255 and can now, working toward both sides, compare band for band. — (3) If the spectroscope has no scale, we make use of the spark spectrum of Cd for comparison. We see then that the head of a band lies immediately above a strong green Cd line. For this line chart 8, No. 72 gives approximately the wave-length 538, so that the sulphur band lies, according to No. 255, at 542, as was found above. — (4) We compare the spark spectrum of lead with No. 112. The spectroscope shows the strong green double line of air which is found to lie at 500 (see above). Thus we at once know two corresponding points in the two spectra.

Importance of the conditions for producing spectra. It is essential always to select spectra from the atlas which were produced in the same way as the spectrum which is being examined. The index on pp. 7 and 9, as well as the descriptions are to be consulted for this purpose. The more noteworthy differences between spark, arc, flame etc. are given there. Further information is to be found in the "Spectroscopic Notes" (see alphabetical index).

List of Chemical Elements and Index to Spectra given in the Charts[*], [**].

The name of the element stands in the first column and in the second its usual symbol. The third column gives the atomic weights with respect to O = 16, the fourth the number of the chart and the last the number of the spectrum. o indicates that the spectrum is wanting. sp before a number indicates spark spectrum; arc, arc spectrum; fla, flame spectrum; V vacuum tube.

Element	Symbol	At. wt.	Chart	Number
Aluminium	Al	27.1	9, 10	arc 81, 91; sp. 82
Antimony	Sb	120.2	11, 12	arc 105; sp. 106, 116
Argon	A	39.9	27, 28	V 264, 265, 274, 275
Arsenic	As	75.0	11, 12	arc 103; sp. 104, 114; V 113
Barium	Ba	137.4	5, 6	arc 46, 56; sp. 47, 57; Fla 48, 58
Beryllium	Be	9.1	3	arc 26; sp. 27
Bismuth	Bi	208.5	11, 12	arc 107, 117; sp. 108, 118
Boron	B	11	7, 8	arc 68, 78; sp. 69, 79; Fla 70, 80
Bromine	Br	79.96	25, 26	V 250, 260
Cadmium	Cd	112.4	7, 8	arc 61, 71; sp. 62, 72
Caesium	Cs	132.9	3, 4	arc 23, 33; sp. 24, 34; Fla 25, 35
Calcium	Ca	40.1	3, 4, 5, 6	arc 30, 40; sp. 41, 51; Fla 42, 52
Carbon	C	12.00	10, 27, 28	arc 266, 276; sp. 92, 267, 277, 278; V 269, 279; Fla 268
Cerium	Ce	140.25	15, 16	arc 141, 151; sp. 142, 152
Chlorine	Cl	35.45	25, 26	V 249, 259, 257, 258
Chromium	Cr	52.1	19, 20	arc 183, 193; sp. 184, 194
Cobalt	Co	59.0	4, 19, 20	arc 189, 199; sp. 190, 200; Fla 36
Copper	Cu	63.6	23, 24	arc 221, 231; sp. 222, 232; Fla 223, 233
Erbium	Er	166	15, 16, 17, 18	arc 150, 160; sp. 161, 171
Fluorine	Fl	19	o	o
Gadolinium	Gd	156	15, 16	arc 148, 158
Gallium	Ga	70	o	o
Germanium	Ge	72.5	o	o
Gold	Au	197.2	23, 24	arc 226, 236; sp. 227, 228, 237
Helium	He	4	27, 28	V 263, 273
Holmium	Ho	?	15, 16	arc 149, 159
Hydrogen	H	1.008	27, 28	V 262, 272; Fla 268
Indium	In	114	9, 10	arc 83, 93; sp. 84, 94; Fla 85
Iodine	I	126.85	27, 28	V 261, 271
Iridium	Ir	193	21, 22	sp. 208; arc 218
Iron	Fe	55.9	8, 19, 20, 26	arc 187, 197; sp. 188, 198, 251; Fla 77
Krypton	Kr	81.8	o	o
Lanthanum	La	138.9	13, 14	arc 127, 137; sp. 128, 138
Lead	Pb	206.9	11, 12	arc 101, 111; sp. 102, 112, 115; Fla 119, 120
Lithium	Li	7.03	1, 2	arc 1, 11; sp. 2, 12; Fla 3, 13
Magnesium	Mg	24.36	3, 4	arc 28, 38; sp. 29, 39, 37
Manganese	Mn	55.0	10, 19, 20	arc 185, 195; sp. 186, 196; Fla 95
Mercury	Hg	200	7, 8	arc 63, 64, 73, 74; sp. 65, 75; V 66, 67, 76
Molybdenum	Mo	96.0	17, 18	arc 167, 177; sp. 168, 178
Neodymium	Nd	143.6	15, 16	arc 145, 155; sp. 146, 156
Neon	Ne	20	o	o
Nickel	Ni	58.7	21, 22	arc 201, 211; sp. 202, 212

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[*] The values of atomic weights are taken from the Physical. Chem. Centralblatt 1904.

[**] Spectra of compounds, as Cy, H_2O, CO, $SnCl_4$ are placed under the distinctive element in each case.

Element	Symbol	At. wt.	Chart	Number
Niobium	Nb	94	13, 14	arc 121, 131; sp. 122, 132
Nitrogen	N	14.04	23, 24, 27, 28	sp. 229, 233, 239; V 230, 240, 267, 277
Osmium	Os	191	21, 22	arc 207, 217
Oxygen	O	16	24, 25, 26	sp. 239; V 243, 253
Palladium	Pd	106.5	21, 22	arc 205, 215; sp. 206, 216
Phosphorus . . .	P	31.0	25, 26	arc 241; V 242, 252
Platinum	Pt	194.8	21, 22, 24	arc 209, 219; sp. 210, 220, 238
Potassium	K	39.15	1, 2	arc 7, 17; sp. 8, 18; Fla 9, 19
Praseodymium . .	Pr	140.5	15, 16	arc 143, 153; sp. 144 154
Radium	Ra	225	0	0
Rhodium	Rh	103.0	21, 22	arc 204, 214
Rubidium	Rb	85.4	1, 2, 3, 4	arc 10, 20; sp. 21, 31; Fla 22, 32
Ruthenium . . .	Ru	101.7	21, 22	arc 203, 213
Samarium	Sm	150	15, 16	arc 147, 157
Scandium	Sc	44.1	0	0
Selenium	Se	79.2	25, 26	V 246, 256
Silver	Ag	107.93	23, 24	arc 224, 234; sp. 225, 235
Silicon	Si	28.4	11	arc 109; sp. 110
Sodium	Na	23.05	1, 2	arc 4, 14; sp. 5, 15; Fla 6, 16
Strontium	Sr	87.6	5, 6	arc 45, 53; sp. 44, 54; Fla 43, 55
Sulphur	S	32.06	25, 26	V 244, 245, 254, 255
Tantalum	Ta	183	0	0
Tellurium	Te	127.6	25	arc 247; sp. 248
Terbium	Tb	160	0	0
Thallium	Tl	204.1	9, 10	arc 86, 96; sp. 87, 97; Fla 88
Thorium	Th	232.5	17, 18	arc 164, 174, sp. 165, 175
Thulium	Tm	171	0	0
Tin	Sn	119.0	9, 10, 26	arc 89, 99; sp. 90, 100; Fla 98; V 257, 258
Titanium	Ti	48.1	17, 18	arc 169, 179; sp. 170, 180
Tungsten	Wo	184	17, 18	arc 162, 172; sp. 163, 173
Uranium	U	238.5	17, 18	sp. 166, 176
Vanadium	V	51.2	19, 20	arc 181, 191; sp. 182, 192
Xenon	X	128	0	0
Ytterbium	Yb	173	13, 14	arc 129, 139; sp. 130, 140
Yttrium	Y	89	13, 14	arc 125, 135; sp. 126, 136
Zinc	Zn	65.4	5, 6	arc 49, 59; sp. 50, 60
Zirconium	Zr	90.6	13, 14	arc 123, 133; sp. 124, 134

Luminous Sources.

	Chart	Number		Chart	Number
Sun	27, 28	270, 280	Coalgas flame . .	27, 28	268
Carbon arc*) . . .	27, 28	266, 276	Carbon spark*) . .	27, 28	267, 277

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*) Comp p. 7 under "Carbon".

Index to Charts.

— indicates that the term omitted is the same as that in the corresponding column to the left.
Under λ is given the spectral region in $\mu\mu$.

Chart 1	No	Element	Kind of Spectrum	λ	**Chart 2**	No.	Element	Kind of Spectrum	λ
	1	Lithium	arc	250—500		11	—	—	430—685
	2	„	spark	260—510		12	—	—	430—685
	3	„	flame	300—550		13	—	—	440—695
	4	Sodium	arc	250—500		14	—	—	430—685
	5	„	spark	250—500		15	—	—	430—685
	6	„	flame	250—500		16	—	—	430—685
	7	Potassium	arc	300—550		17	—	—	450—755
	8	„	spark	300—550		18	—	—	450—755
	9	„	flame	300—550		19	—	—	450—755
	10	Rubidium	arc	310—560		20	—	—	420—680
Chart 3					**Chart 4**				
	21	Rubidium	spark	230—480		31	—	—	420—675
	22	„	flame	320—570		32	—	—	420—675
	23	Caesium	arc	330—580		33	—	—	450—705
	24	„	spark	320—570		34	—	—	450—705
	25	„	flame	330—580		35	—	—	450—705
	26	Beryllium	arc	230—480		36	Cobalt	flame	320—570
	27	„	spark	230—480		37	Magnesium	spark with self-induction	380—635
	28	Magnesium	arc	270—520		38	—	—	450—705
	29	„	spark	270—520		39	—	—	470—725
	30	Calcium	arc	290—540		40	—	—	450—705
Chart 5					**Chart 6**				
	41	Calcium	spark	250—500		51	—	—	450—705
	42	„	flame	330—580		52	—	—	460—715
	43	Strontium	flame	260—510		53	—	arc	450—705
	44	„	spark	250—500		54	—	—	470—725
	45	„	arc	310—560		55	—	flame	460—715
	46	Barium	arc	230—480		56	—	—	450—715
	47	„	spark	220—470		57	—	—	470—725
	48	„	flame	330—580		58	—	—	450—705
	49	Zinc	arc	250—500		59	—	—	450—705
	50	„	spark	250—500		60	—	—	450—705
Chart 7					**Chart 8**				
	61	Cadmium	arc	220—470		71	—	—	450—705
	62	„	spark	220—470		72	—	—	450—705
	63	Mercury	arc in vacuum	320—570		73	—	—	400—655
	64	„	arc in air	230—480		74	—	—	430—685
	65	„	spark	230—480		75	—	—	420—675
	66	„	vacuum tube	240—490		76	—	—	420—675
	67	„	band	250—500		77	Iron	flame	320—570
	68	Boron	arc	250—500		78	—	—	440—695
	69	„	spark (without self-induction)	220—470		79	Boron	spark with self-induction	380—635
	70	„	flame	300—550		80	—	—	430—685

Chart 9	No.	Element	Kind of Spectrum	λ	**Chart 10**	No.	Element	Kind of Spectrum	λ
	81	Aluminium	arc	220—470		91	—	—	390—645
	82	"	spark	230—480		92	Carbon	spark in coal-gas	240—490
	83	Indium	arc	230—480		93	—	—	440—695
	84	"	spark	240—490		94	—	—	410—665
	85	"	flame	310—560		95	Manganese	flame	320—580
	86	Thallium	arc	230—480		96	—	—	390—645
	87	"	spark	220—470		97	—	—	420—675
	88	"	flame	320—570		98	Tin	flame	280—530
	89	Tin	arc	260—510		99	—	—	450—705
	90	"	flame	240—490		100	—	—	450—705
Chart 11	101	Lead	arc	230—480	**Chart 12**	111	—	—	440—695
	102	"	spark	220—470		112	—	—	400—655
	103	Arsenic	arc	220—470		113	Arsenic	vacuum tube	400—655
	104	"	spark	210—460		114	—	—	410—665
	105	Antimony	arc	230—480		115	Lead	spark with self-induction	390—645
	106	"	spark	210—460		116	—	—	450—705
	107	Bismuth	arc	220—470		117	—	—	450—705
	108	"	spark	220—470		118	—	—	450—705
	109	Silicon	arc	240—490		119	Lead	flame	330—580
	110	"	spark	230—480		120	Lead	flame	390—645
Chart 13	121	Niobium	arc	220—470	**Chart 14**	131	—	—	430—685
	122	"	spark	220—470		132	—	—	430—685
	123	Zirconium	arc	230—480		133	—	—	430—685
	124	"	spark	230—480		134	—	—	—
	125	Yttrium	arc	240—490		135	—	—	380—635
	126	"	spark	220—470		136	—	—	410—665
	127	Lanthanum	arc	250—500		137	—	—	420—675
	128	"	spark	220—470		138	—	—	420—675
	129	Ytterbium	arc	250—500		139	—	—	410—665
	130	"	spark	220—470		140	—	—	440—695
Chart 15	141	Cerium	arc	280—530	**Chart 16**	151	—	—	440—695
	142	"	spark	230—480		152	—	—	410—665
	143	Praseodymium	arc	250—500		153	—	—	420—675
	144	"	spark	250—500		154	—	—	420—675
	145	Neodymium	arc	250—500		155	—	—	420—675
	146	"	spark	250—500		156	—	—	400—655
	147	Samarium	arc	230—480		157	—	—	430—685
	148	Gadolinium	arc	230—480		158	—	—	430—685
	149	Holmium	arc	250—500		159	—	—	400—655
	150	Erbium	arc	230—480		160	—	—	420—675
Chart 17	161	Erbium	spark	230—480	**Chart 18**	171	—	—	420—675
	162	Tungsten	arc	230—480		172	—	—	430—685
	163	"	spark	230—480		173	—	—	390—645
	164	Thorium	arc	250—500		174	—	—	420—675
	165	"	spark	220—470		175	—	—	420—675
	166	Uranium	spark	230—480		176	—	—	420—675
	167	Molybdenum	arc	230—480		177	—	—	440—695
	168	"	spark	230—480		178	—	—	440—695
	169	Titanium	arc	240—490		179	—	—	430—685
	170	"	spark	230—480		180	—	—	440—695

Chart 19	No.	Element	Kind of Spectrum	λ	Chart 20	No.	Element	Kind of Spectrum	λ
	181	Vanadium	arc	230—480		191	—	—	430—685
	182	"	spark	220—470		192	—	—	430—685
	183	Chromium	arc	220—470		193	—	—	430—685
	184	"	spark	230—480		194	—	—	440—695
	185	Manganese	arc	230—480		195	—	—	420—675
	186	"	spark	230—480		196	—	—	390—645
	187	Iron	arc	210—460		197	—	—	430—685
	188	"	spark	210—460		198	—	—	370—625
	189	Cobalt	arc	240—490		199	—	—	420—675
	190	"	spark	210—460		200	—	—	380—635
Chart 21					**Chart 22**				
	201	Nickel	arc	230—480		211	—	—	430—685
	202	"	spark	220—470		212	—	—	370—625
	203	Ruthenium	arc	220—470		213	—	—	440—695
	204	Rhodium	arc	220—470		214	—	—	460—715
	205	Palladium	arc	220—470		215	—	—	460—715
	206	"	spark	220—470		216	—	—	440—695
	207	Osmium	arc	220—470		217	—	—	440—695
	208	Iridium	spark	230—480		218	Iridium	arc	440—695
	209	Platinum	arc	220—470		219	—	—	440—695
	210	"	spark	210—460		220	—	—	410—665
Chart 23					**Chart 24**				
	221	Copper	arc	210—460		231	—	—	420—675
	222	"	spark	210—460		232	—	—	420—675
	223	"	flame	330—580		233	Copper	spark with electrodes near together	280—535
	224	Silver	arc	250—500		234	—	—	390—645
	225	"	spark	220—470		235	—	—	390—645
	226	Gold	arc	220—470		236	—	—	400—655
	227	"	spark	230—480		237	—	—	430—685
	228	"	spark with self-induction	230—480		238	Platinum	spark with self-induction	210—460
	229	Nitrogen	lines in vacuum	320—570		239	—	—	410—665
	230	"	bands in vacuum tube	260—510		240	—	—	410—665
Chart 25					**Chart 26**				
	241	Phosphorus	arc	220—470		251	Iron	spark with self-induction	390—645
	242	"	vacuum tube	230—480		252	—	—	420—675
	243	Oxygen	vacuum tube	240—490		253	—	—	390—645
	244	Sulphur	vacuum tube lines	300—550		254	—	—	400—655
	245	"	bands	250—500		255	—	—	420—675
	246	Selenium	vacuum tube lines	230—480		256	—	—	390—645
	247	Tellurium	arc	220—470		257	$SnCl_4$	vacuum tube	260—515
	248	"	spark	220—470		258	$SnCl_4$	vacuum tube	410—665
	249	Chlorine	vacuum tube lines	300—550		259	—	—	410—665
	250	Bromine	vacuum tube lines	280—530		260	—	—	460—715

Chart 27	No.	Element	Kind of Spectrum	λ	**Chart 28**	No.	Element	Kind of Spectrum	λ
	261	Iodine	vacuum tube line	240—490		271	—	—	400—655
	262	Hydrogen	vacuum tube	290—540		272	—	—	430—685
	263	Helium	vacuum tube	270—520		273	—	—	430—685
	264	Argon	vacuum tube red spectr.	320—570		274	—	—	370—625
	265	"	vacuum tube blue spectr.	320—570		275	—	—	380—635
	266	Carbon	arc	270—520		276	—	—	410—665
	267	"	spark	230—480		277	—	—	420—675
	268	"	coalgas-flame	240—490		278	Carbon	spark with self-induction	370—625
	269	"	CO in vacuum tube	290—540		279	—	—	420—675
	270	Sun	—	320—570		280	—	—	450—715

Description of the Charts.

Introductory Remarks.

In the following description the numbers corresponding to two charts are placed together when these charts are parts of the same spectrum.

Under "*Material*" the manner of production of the spectrum is given. For more detailed description the reader is referred to the corresponding portions of the "Spectroscopic Notes".

Under "*Correction*" is found the number to be added to the scale reading to obtain the correct fourth place for the wave-length value.

Under "*Impurities*" the elements or compounds are given to which the strongest foreign lines belong. Among the impurities occurring most frequently may be mentioned the cyanogen bands, occurring in almost all arc and spark spectra (especially the band at λ 3884), the strongest lines of calcium (λ 3934 and λ 3969 = K and H of the solar spectrum, and λ 4227 = g of the solar spectrum), of aluminium (λ 3944 and λ 3962), of sodium (λ 5890 and λ 5896 = D-lines), of carbon (λ 2478, λ 4267, λ 6579/84), of air (e. g. λ 3995, λ 4630/42/48, λ 5003/06, λ 5679, λ 5933/43, λ 6563), of potassium (λ 4044/47) and of iron (λ 4046, λ 4384). These are designated briefly by the symbols Cy, Ca, Al, Na, C, N, K, Fe. Certain impurity lines, whose positions might give rise to confusion, are specially noted.

Under "*Remarks*" a short catalogue is given of what is to be seen in the reproduction*). Lines belonging to series receive especial attention, the series being in each case clearly indicated and the series numbers of the lines given. When confusion might occur, lines belonging together are enclosed in brackets. The wave-lengths of the strongest lines are printed in italics.

For spectra with numerous lines, where complete tables could not be given, a list of notably strong and easily identified lines is given in each case. The lines chosen are distributed as uniformly as possible over the whole spectrum, and as far as possible only simple lines are so listed. The necessary correction has always been allowed for in the numbers given in the description.

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*) Not in the negative, which usually shows much more.

**) Designation of intensity by numbers is omitted on account of the varying sensitiveness of different photographic plates and of the eye.

Finally, notes on the differences between spark, arc and flame spectra are included. These are by no means complete and are limited to especially characteristic examples*).

Charts I and II.

1 and 11. **Lithium Arc.**

Material: Metal in carbon arc.

Impurities: Cy, Ca, Al, Na.

Remarks. Besides the lines of the principal series and of the two subseries, two members of a third subseries are to be seen at 464 and 415. In (11) the blue line at 4602 and the red line at 6708 are reversed (lens). The orange line at 6104 shows some ghosts. Lines of the principal series are at *6708*, 3233, 2741 (n = 3, 4, 5), of the first subseries at 6104, *4602*, 4132, 3915, 3795, 3721, 3672 (n = 3, ... 9), of the second subseries at 4972, 4273, 3986, 3836 (n = 4, ... 7).

2 and 12. **Lithium Spark.**

Material: (2) spark between metallic poles in hydrogen atmosphere; (12) Li_2CO_3 on carbon points, self-induction, air-blast.

Impurities: in (2) hydrogen lines at 486 and 434, in (12) Na.

Remarks. Lines of principal series at *6708* (lens, r); of first subseries at 610, 460 (lens, r), 413. — The H lines are broadened.

3 and 13. **Lithium Flame.**

Material: Li_2CO_3 on small carbon rods in coalgas-oxygen flame.

Impurities: in (3) Ca 4227, K 4044, 4047, H_2O band at 310, hydrocarbon band at 431; in (13) Na.

Remarks. Lines of principal series at *6708* (lens, r), of first subseries at 610, 460 (lens), 413. In Bunsen flame *6708*, 6104 appear.

4 and 14. **Sodium Arc.**

Material: Metal in carbon arc.

Impurities: Cy, Ca, Al.

Remarks. In (14) the D lines appear reversed, but still separated (lens). Pairs of principal series at *5890/96*, 3303, 2853, 2680 (n = 3, 4, 5, 6), of first subseries at 568, 498, 467, 450, 439, 432 (n = 4, ... 9), of second subseries at 6161/55, 515 (lens), 475, 454, (n = 4, ... 7).

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*) The material is wanting for a systematic comparison of spectra given by different conditions. Only when detailed studies of single elements are carried out in greater number on the plan of the works by EBERHARD, DE GRAMONT, HARTMANN, KING, EDER and VALENTA will it be possible to make positive statements concerning the behavior of single lines of a spectrum and to explain the numerous differences in the statements of different observers.

5 and 15. Sodium Spark.

Material: (5) spark between metallic poles in hydrogen;
(15) Na_2CO_3 on carbon points, self-induction, air-blast.

Impurities: in (5) hydrogen at 486, 434, 410, 386; Ca.

Remarks. Pairs of principal series at *589* (broadened), 330, 285 (lens), of first subseries at 568, 498 (lens), 467 (lens), of second subseries at 616. The hydrogen lines are much broadened, that at 486 reversed.

6 and 16. Sodium Flame.

Material: Na_2CO_3 on small carbon rods in coalgas-oxygen flame.

Impurities: K 4044 and 4047.

Remarks. Between 340 and 500 a continuous spectrum is to be seen. The D lines are broadened and reversed and run together in the middle. Lines of the principal series at *589*, 330; of the first subseries at 568, 498, 467, 450; of the second subseries at 475 (lens). In Bunsen flame 5896/90 appear.

7 and 17. Potassium Arc.

Material: metal in carbon arc.

Impurities: (7) Cy, Ca, Al, Na 3303; (17) Na.

Remarks. Pairs of principal series (lens) at *4045* 3447, 3217 (lens), (n = 4, 5, 6); of first subseries at 6939/11 (lens), 5802/782, 5340/24, 5100/085, 4957/43, 4864/51 (n = 4, ...9); of second subseries at 5832/12, 5360/43, 5112/098 (lens), 4966/52 (n = 5, ...8). The pair n = 9 is indistinct, and only a trace of n = 10 appears in (17). The D lines, given by impurities, are reversed (lens).

8 and 18. Potassium Spark.

Material: (8) spark between metallic poles in hydrogen;
(18) K_2CO_3 on carbon points, self-induction, air-blast.

Impurities: (8) H lines at 486, 434, 411; (18) Na.

Remarks. Pairs of principal series at *404*, 345; of first subseries at 5802/782, 5340/24; of second subseries at 5832/12, 5360/43. Numerous weaker spark lines appear, e. g. at 4186, 3898. The H lines are broadened, that at 486 reversed.

9 and 19. Potassium Flame.

Material: Potassium formiate (HCO_2K) on small carbon rods in coalgas-oxygen flame.

Impurity: Na.

Remarks. Between 350 and 560 is continuous spectrum. The gap in this at 500 arises from the unequal sensitiveness of the photographic plate. Pairs of principal series are at *404* and 345, of first and second subseries at 580, 535, 510 (for series numbers see spectra 7 and 17). In Bunsen flame 7699/65 and 4044/47 appear.

10 and 20. Rubidium Arc.

Material: Rb_2CO_3 in carbon arc.

Impurities: Na, Ca 4227.

Remarks. Pairs of principal series at *4216/02* (reversed, lens), 3592/87; of first subseries at 6299/07, 5724/648, 5431/363, 5260/195, 5151/088, 5076 (n = 5, ... 10); of second subseries at 6160/071, 5654/579, 5390/22, 5234 (n = 5, ... 7). The pairs of the first subseries are stronger throughout than those of the second.

Charts III and IV.

21 and 31. **Rubidium Spark.**

Material: (21) spark between carbon points with Rb_2CO_3;
(31) same with self-induction and air-blast.

Impurities: (21) Cy, Ca (H and K, 4227, group 428—423, 4455/35/26), N (4447, 4631/43/49); (31) Na, Ca (4227, 4303, 4455/35), Ba (4554), Sr (4607), Mg (5173/84).

Correction: from 500 toward ultra-violet + 3.

Remarks. Pairs of principal series at *4216/02*; of first subseries at 6299/07, 5724/648, 5431; of second subseries at 6160, 5654.

22 and 32. **Rubidium Flame.**

Material: Rb_2CO_3 on small carbon rods in coalgas-oxygen flame.

Impurities: Na, K (4044/47), Ba 4554.

Correction: (22) — 1.

Remarks. Between 370 and 570 is a continuous spectrum with photographic minimum at 5000. Pairs of principal series at *420* and 359 (compare above); of first subseries at 630/20, 572/65, 543/36, 526/19, 515/09, 5088, 5076 (n = 5, ... 10); of second subseries at 616/07, 565/58, 539/32, 523 (lens), and also 5165. At 550 the ground begins to resolve into lines (lens). It seems therefore as if the continuous ground is really formed by a band spectrum, perhaps that of rubidium. In the Bunsen flame appear most of the lines mentioned above, the strongest being 7811, 6298, 4215/02.

23 and 33. **Caesium Arc.**

Material: Cs_2CO_3 in carbon arc.

Impurities: Cy, Ca, Al, Sr (4607), Rb (4202/16), K (4044/47), Ba (5536), Na.

Correction: (23) — 2.

Remarks. Pairs of principal series at *4593/55*, 3889/77 (lens), 3617/12 (lens) (n = 4, 5, 6). Pairs of first subseries at 6724, 6213/010, 5845/664, 5635/466, 5503/341, 5414/257, 5351 (n = 4, ... 10); of second subseries at 6354, 6034/5840 (lens), 5746/569 (lens) (n = 4, 5, 6), also 6217 (lens).

24 and 34. **Caesium Spark.**

Material: (24) spark between carbon points with Cs_2CO_3;
(34) same with self-induction and air-blast.

Impurities: Na, Cy, Ca, B (in 24).

Remarks. Pairs of principal series at *4593/55*, 3889/77; of first subseries at 621/01, 585/66; of second subseries at 603.

25 and 35. Caesium Flame.

Material: Cs_2CO_3 on small carbon rods in coalgas-oxygen flame.

Impurities: Na, K (4044/47), Rb (4202/16), Ca.

Remarks. Pairs of principal series at *4593/55*, 3889/77; of first subseries at 672, 621/01, 585/66, 563/46, 550/34, 541/25, 5351/199, 5304 (n = 4, ... 11), of second subseries at 6354, 603/584, 5746, 5408 (lens) (n = 4, ...7). All of these lines appear in the Bunsen flame, the strongest being 6010 and *4593/55*.

26. Beryllium Arc.

Material: beryllium oxide in carbon arc.

Impurities: Cy, Ca, Al.

Remarks. All lines known to belong to beryllium are visible, viz. 2349 (lens), 2495 (lens), 2651, *3131* (pair, strongest), 3321 (pair), 4573 (lens).

27. Beryllium Spark.

Material: spark between carbon points with beryllium oxide.

Impurities: Cy, Ca.

Correction: + 2.

Remarks. The same lines appear as in (26). λ *3131* is strengthened and is seen to be a pair (lens).

28 and 38. Magnesium Arc.

Material: arc between metal rods.

Impurity: Na.

Remarks. Triplets of first subseries at [3838/33/30] (lens, broadened), [3097/93/91] (lens), [2852/49/47] (concealed by the reversed line *2852*) (n = 4, 5, 6); of second subseries at [*5184*/73/68], [3337/32/30] (lens), [2942/39/37] (lens), [278] (lens) (n = 3, 4, 5, 6). Lines of isolated series at *5529*, 4703, 4352, 4058. Bands of MgO at 5000 (lens). The spark line 4481 is absent. Compare with spark spectra in (29), (39), (37).

37. Magnesium Spark.

Material: spark between metallic poles, self-induction.

Impurity: Ca.

Remarks. The less refrangible part of the spectrum shows the transition between spark and arc spectra. Besides the lines given under (28) the spark line 4481 appears. This line is strongest at the electrodes and is there broadened (the lower half appears in the reproduction). The spark lines are weakened by self-induction, 2929/37 and 4481 showing the greatest difference. λ 4571 is strengthened.

29 and 39. Magnesium Spark.

Material: spark between metallic poles.

Impurities: Na, air (at 593, 594, 566—90, 553, 504, 500, 478—484.

Remarks. The lines of the isolated series are much weakened. The intensity maximum is moved toward the violet (compare Nos. 28 and 37). Numerous lines are strengthened, e. g. 5712, *4481* (spark line), 2916/29/37, 2803, 2791/96/98 (the points appear below).

36. **Cobalt Flame.**

Description under chart XXI, after No. 190.

30 and 40. **Calcium Arc.**

Material: calcium chloride in carbon arc.

Impurities: Na, Cy.

Correction: (40) + 1.

Remarks. Triplets of first subseries at [4457/56/55 (broadened), 4436/35 (lens), 4426], [3644 (double, lens), 3631 (double, lens), 3624], [3362, 3350, 3345], [3226, 3215, 3210] (lens) (n = 4, 5, 6, 7); of second subseries at [6162, 6122, 6103], [3974, 3957, 3949], [3488, 3475, 3469] (lens), [3286, 3275], [3181] (n = 3 .... 7). Isolated triplets: [4319, 4299, 4290], [4847, 4823, 4808 (No. 40, lens)]. Denser isolated triplets at [5602, 5595, 5590], [5270, 5264, 5261], [4586, 4582, 4579], [4099, 4095, 4093]. Series A (consisting of pairs) at [*3969*, *3934*, H and K of solar spectrum, broadened, reversed], [3737, 3706], [3180, 3159]. Isolated narrow pairs at [6494, 6450], [4303, 4283], [3007, 2997 (lens)]. Isolated lines at 6717 (lens), 6500, 6472/63, 6167, 5858, 5603, 5599/89/82/13, 5350, 5189, 5042, 4878, 4527, 4355, 4308, *4227*. The strong line 4227 (g of solar spectrum) is broadened and reversed (lens). The reversal widens trumpet-shaped at the ends. At 550 and 590—630 the bands of calcium oxide (?) are seen. Numerous heads may be observed (e. g. at 6211) and indications of a resolution in lines (e. g. at 595, lens). Such bands seem of a different kind from those with sharp limits at one end, as Cy, C, Co, Pb, Sn etc.

Charts V and VI.

41 and 51. **Calcium Spark.**

Material: spark between carbon points with calcium chloride.

Impurities: air spectrum, Cy, Na.

Remarks. The strongest lines of the arc appear in the spark; but the subseries (see above) are weakened relatively to the pairs of series A, which are stronger even than 4227. The pairs are strengthened. A number of arc lines are weakened or absent, e. g. 6472/50, 4878, 4527, 4355, 3949. The calcium bands appear, though weaker than in the arc. The use of self-induction strengthens the bands and the isolated lines, while it weakens the isolated pairs.

42 and 52. **Calcium Flame.**

Material: calcium chloride on small carbon rods in coalgas-oxygen flame.

Impurities: Na (5890/96).

Remarks. In the flame the calcium bands predominate, only the line 4227 appearing besides. The Bunsen flame gives the same spectrum. According to Eder and Valenta* the bands at 644, 626, 598 and all toward shorter wave-length belong to the oxide, the others to the chloride.

43 and 55. Strontium Flame.

Material: strontium nitrate on small carbon rods in coalgas-oxygen flame.

Impurities: Na, Ca (4227, bands at 554, 593), K (4044/47, lens).

Remarks. The band spectrum of the oxide (?) predominates in the strontium flame, bands appearing as high as 693 and as low as 365. Besides these, the strong flame line *4608* appears and the lines 4216 and 4078 very much weaker (lens). The last two cannot be seen in the Bunsen flame. The more refrangible bands appear to be shaded in the opposite direction from those in the red and yellow. According to Eder and Valenta the bands 683, 646 and those of shorter wave-length belong to the oxide, those at 673 and 635 to the chloride (?).

45 and 53. Strontium Arc.

Material: strontium nitrate in carbon arc.

Impurities: Na, Cy, Ca (616, 612, 600, 585, group at 560, 526).

Correction: (55) + 1.

Remarks. Lines of first subseries are visible at [4972/68/62, 4876/73, 4832], [4033/30, —, —] (n = 4, 5); of second subseries at [4438, 4362, 4327 (lens)]. Isolated pairs at [6551, 6387], [4812, 4722]; pairs with the double vibration difference at [5451, 5222], [4306, 4162], [*4216*, *4078*]. Isolated triplets at [5535, 5504, 5486], [5257, 5230, 5213], [4892, 4869, 4855], [4338, 4319, 4308]. Among the isolated lines are 6818 (?), 6504, 6409, 6381, 5544/40/22, 5481, 5239/25, 5156, 4784, 4742/22, 4678, *4608*, 4532, 4162 (lens), 3465 (lens).

44 and 54. Strontium Spark.

Material: spark between carbon points with strontium nitrate.

Impurities: air spectrum, Ca.

Remarks. All of the stronger arc lines appear in the spark (see 45). Many of these are relatively stronger in the spark, e. g. *4306*, *4216*, *4162*, 4078, 3475/65, 3381. Some are weakened, as 4338.

46 and 56. Barium Arc.

Material: barium chloride in carbon arc.

Impurities: Ca, Na, Mg, Sr (4078).

Remarks. The Ba pairs corresponding to the isolated pairs of Mg, Ca, Sr, viz [*6497*, 5854], [*4934*, *4554*], [4900, 4525], [4166, 3892] are to be seen. No series are known. Among the isolated lines are those at 6697/77, 6596/28, 6499 (lens), 6483, 6451, 6342, *6142*/11, 6063/20, 5997/72, 5908, 5827/06/01, 5778, 5680, *5536*/19, 5425, 4727/01, 4692/74/00, 4580/74, 4524 (lens) /06, 4494/89, 4432/03, 4351, 4283,

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*) See Beiträge, p. 92.

4131, 3996/94, 3938/36/10 (lens), 3545/25/01, 3421, 3377 (lens), 3072, 2335 (lens). The line 4554 is much broadened.

47 and 57. Barium Spark.

Material: spark between carbon points with barium chloride.

Impurities: air lines, Mg (2803, 2796).

Remarks. The Ba spark gives the stronger arc lines (see 46), but with some differences. The arc lines above 614 are weakened (with the exception of 6497 and 6342), also 5908, 4554, 4494/89, 3910. Below 389 all arc lines are weakened except 3501 (lens), 3072, 2335, 2305 (lens).

48 and 58. Barium Flame.

Material: (48) barium chloride on small carbon rods in coalgas-oxygen flame.

(58) the same, but with barium hydroxide.

Impurities: Ca 4227, Na, Sr 4608, K 4044/47 (lens).

Remarks. 5536 appears as the flame line of barium. The ground is filled with bands. These divide in two classes. These of the first class are diffuse (5137, 5172, 5242, 5316) and are probably due to the chloride. In fact, they are absent in (58), when barium hydroxide was used. The remaining bands are resolved by the lens in fine, regularly placed lines, running together to form heads toward the violet. They belong either to an oxide or to the metal itself. The last is more probable, as the bands in question are entirely different, both in structure and direction of heads from the oxide bands of Ca, Sr etc. The Bunsen flame gives the same spectrum.

49 and 59. Zinc Arc.

Material: arc between zinc rods.

Impurities: Cd 5086, 4800, Pb 4058.

Correction: (49) + 2.

Remarks. As series lines we see for the first subseries [3346/45 (d), 3303/02, 3282], [2802 (three components), 2771 (two components), 2757], [2609 (lens), —] ($n = 4, 5, 6$); second subseries [*4811*, *4722*, *4680*], [3072, 3036, 3019] ($n = 3, 4$). Isolated lines at *6364*, 5182, 4630, 3076. The ultra-violet is relatively weakened through the use of the metal as electrodes, while 6364 is strengthened. The triplet at 47 is reversed (lens).

50 and 60. Zinc Spark.

Material: spark between metallic poles.

Impurities: air spectrum.

Correction: (50) + 2, (60) — 1.

Remarks. The spark spectrum contains the strongest arc lines. In the series, however, the intensity falls off faster for the spark, so the members for $n > 3$ are absent. On the other hand, a number of strong spark lines appear, e. g. 6103, 6024 (diffuse), 5895, *4925*, *4912*; 2558; 5182 is wanting, 6364 is weakened. Self-induction weakens or blots out the spark lines. The lines above 65 belong to the second order spectrum.

Charts VII and VIII.

61 and 71. Cadmium Arc.

Material: arc between metal rods.

Impurities: Na, Tl (5351), Pb (4058).

Remarks. Triplets of first subseries at [3615/13/11 (lens), 3468/66 (lens), 3404], [2981, 2881, 2837], [2764, 2678, 2640], [2660, 2580] (n = 4, 5, 6, 7). Triplets of second subseries at [*5086*, *4800*, *4678*], [3253, 3133, 3081], [2868, 2775] (n = 3, 4, 5). Isolated lines are seen at *6439*, 3261. Compare the spark spectrum.

62 and 72. Cadmium Spark.

Material: spark between metallic poles.

Impurities: air lines at 460—465, 5006, 568.

Remarks. Triplets of first subseries at [3615, 3468, 3404], [2081, 2881, 2837], [2764]; of second subseries at [*5086*, *4800*, *4678*], [3253, 3133, 3081 (lens)]. An isolated line is seen at 2288 (lens), and pairs at [3535, 3251], [2740, 2573]. Spark lines at 2313/21, 2573, 4416, 5338, 5379. At 6933 (lens) a red line appears. Some arc lines, as 6439, 4663 are weakened. Self-induction destroys the spark lines.

63 and 73. Mercury Arc (in vacuum).

Material: Arons mercury arc in glass vessel.

Remarks. The green line at 5461 is strongest. The yellow pair lies at 5770/90, an ultra-violet triplet at 3650/55/63, also lines at 4047/78 and 4358.

64 and 74. Mercury Arc.

Material: metal in carbon arc.

Impurities: Cy 4216, 3884, 3590.

Correction: (64) + 2.

Remarks. Triplets of first subseries at [3663/55/50, 3132/26, 2967], [3025, 2654, 2536] (n = 4, 5); of second subseries at [*5461*, 4359, 4047], [3342, 2894, 2753 (lens)], [2925 (lens)] (n = 3, 4, 5). Isolated lines appear at 5770/90, 4078.

65 and 75. Mercury Spark.

Material: spark between the metal and a carbon point.

Impurities: air lines at 567, 500, 460—465, 445.

Remarks. Besides the series lines mentioned under (64), numerous spark lines are visible, notably at 5670, 5427 (see below), 3985, 3790/55, 2848, while some arc lines, as 4339/48, are lacking. *5461* is strong. 2848, 3790, 3984 are weakened by self-induction.

66 and 76. Mercury Vacuum-tube.

Material: metal in tube of quartz or glass. Capacity in discharge circuit. The mercury distilled through the capillary.

Correction: (66) + 1; (76) + 2.

Remarks. The vacuum tube spectrum combines the lines of the spark spectrum with those of the arc. In addition lines appear which are either new or stronger than in the other spectra, e. g. 6152 (br), 6089 (lens) (?), 5889/81/72/64/19 (br), 5638, 5596, 5427, 5274, 4826, 4487, 4348/40 (weak in spark, strong in arc), 3907, 3860, 3562/44, 3026, 2926, 2807, 2648/41 (lens).

67. Mercury Band-Spectrum.

Material: metal in quartz tube; no capacity in circuit.

Remarks. Besides the stronger lines, bands are to be seen at 4393, 4218, 4018, 3729, 3500, each made up of several series of lines (lens). Compare EDER and VALENTA, Beiträge, p. 150 etc.

77. Iron Flame.

Description under Chart XIX, after No. 189.

68 and 78. Boron Arc.

Material: boracic acid in carbon arc.

Impurities: Cy 4216, 3884, 3590, Na 589, 578.

Remarks. The two boron lines are to be seen at 250 (lens) λ *2498/97*. In addition, a series of diffuse maxima appear at 600, 580, 545, 520, 490, 470, 450, whose distance apart decreases with the wave-length, and which appear also in the boron spark (with self-induction) and in the boron flame, apparently belonging to boracic acid. Finally the whole ground from 350—460 is filled with fine lines of the boron bands (lens), proceeding in series fashion to numerous heads directed toward the violet. Heads of this sort are at 575, 545, 504, 461, 459, 436, 434, 405, 404 etc. The boron lines 2498/97 appear as impurity lines in almost all spectra produced by means of carbon rods, and so are to be found in numerous spectra in the atlas, e. g. 164 and 165 of Chart XVII.

69 and 79. Boron Spark.

Material: (69) spark between carbon points with boracic acid;
(79) same with self-induction and air-blast.

Impurities: (69) air lines, carbon lines; (79) Cy, Na.

Correction: (69) + 2.

Remarks. In (69) the three boron lines *2498/97*, 3451 (lens) appear. All other lines are given by the electrodes. (79) shows the diffuse maxima (see above), as well as indications of the boron band spectrum.

70 and 80. Boron Flame.

Material: boracic acid sticks in coalgas-oxygen flame.

Impurities: Na, hydrocarbon band at 421.

Correction: (70) + 10.

Remarks. The diffuse maxima mentioned under (68) appear. We see also traces of bands, e. g. at 545, which do not appear to be identical with the boron bands composed of fine lines. (Possibly Ca?)

Charts IX and X.

81 and 91. **Aluminium Arc.**

Material: arc between metal rods.

Impurity: Ca.

Correction: (81) + 1; (91) + 1.

Remarks. Besides numerous lines not belonging to series, we see pairs of the first subseries at 3093/82, 2575/68, 2373/67 (n = 4, 5, 6); of the second subseries at *3962/44*, 2660/53, 2379/72 (lens) (n = 3, 4, 5). Between 402 and 550 lies the band spectrum ascribed to aluminimum oxide, consistng of six band groups. The two lines at 6165 and 6186 are from the second order spectrum. Above 4000 Al has no lines in the arc.

82 and 239. **Aluminium Spark.**

Material: spark between metallic poles.

Impurities: air lines.

Remarks. Besides the pairs of the first subseries at 309, 257 (lens) and that of the second subseries 3962/44, the following enhanced lines (spark lines) appear: in (239), 5724, 5697; in (82) 4663/12, 4530, 4513, 3901, 3714/03, 3613, 3602, *3587* (strongest), 2816, 2632. Compare the arc spectrum. Self-induction weakens or blots out these spark lines.

92. **Carbon Spark in Coalgas.**

Description under Chart XXVII, after No. 278.

83 and 93. **Indium Arc.**

Material: indium hydroxide in carbon arc.

Impurities: Ca, Al, Na, Cy, Ba 4934, Ca 5270.

Remarks. Belonging to the pairs of the first subseries we see [3259/56 (lens), 3039], [2714/10, 2560], [2523/21 (lens)] (n = 4, 5, 6); of the second subseries the pairs [*4511* (strongest line), 4102], [2933, 2754 (lens)], [2602] (n = 3, 4, 5). Above 4511 indium has no lines in the arc.

84 and 94. **Indium Spark.**

Material: spark between carbon points with indium hydroxide.

Impurities: air lines, Ca 4227, C 2478.

Remarks. Pairs of first subseries at [3259/56 (lens), 3039] [2714 (lens)]; of second subseries at [*4511, 4102*] [2933]. Enhanced (spark) lines at 6090 (lens), 5821 (lens), 5251, 4681, 4657, 4640, 3008, 2984, 2941, 2890 (lens), 2841. The lines 3259/56 of the second order appear at 6517.

85. Indium Flame.

Material: small carbon rods with indium hydroxide in coalgas-oxygen flame.
Impurities: K 4044/47, Rb 4202/16 (lens), Mn 4031/33/35 (lens).
Correction: — 1.

Remarks. Only the lines 4511 and 4102 appear. There are none of greater wave-length. The same appear in the Bunsen flame.

95. Manganese Flame.

Description under Chart XIX, after No. 186.

86 and 96. Thallium Arc.

Material: arc between metal rods.
Impurities: Ca 4227 (in 96), Mg 5529.
Correction: (86) + 1.

Remarks. Pairs of first subseries appear at [3530/19 (lens), 2768], [2922/18 (lens), —], [2711, —], (n = 4, 5, 6); of second subseries at [*5351*, *3776*], [3230, 2580], [2826, —], [2666, —] (n = 3, 4, 5, 6). The lines of the spectrum show good examples of diffuse, broadened and reversed lines, as well as of different behavior of single lines. Compare the corresponding lines in the spark spectrum.

87 and 97. Thallium Spark.

Material: spark between metallic poles.
Impurities: air lines.

Remarks. The spark spectrum being stronger in the ultra-violet than the arc spectrum, a number of series lines appear besides those given under (86), viz. of first subseries, [3530/19, 2768], [2922/18, 2380], [2711, —], [2610 (lens), —] (n = 4 . . . . 7): of second subseries [*5351*, 3776], [3230, —], [2826, —], [2666 (lens), —]; also numerous spark lines, e. g. 5949, 5154, 5079, 4983, *4737*, 3092, 2531, 2298.

88. Thallium Flame.

Material: thallium nitrate on small carbon rods in coalgas-oxygen flame.
Impurities: Ca 4227, K 4044/47, Ba 4554 (lens).
Correction: — 3.

Remarks. The lines *5351* (unsymmetrically broadened), 3776 (unsymmetrically broadened and reversed [lens]) of the second subseries and the pair 3530/19 (lens) of the first subseries appear. At 554 is a diffuse band (thallium oxide?). 5351 appears in the Bunsen flame.

98. Tin Flame.

Material: chloride on small carbon rods in coalgas-oxygen flame.
Impurities: Pb 4058.
Correction: — 2.

Remarks. It may be seen at 40 (lens) that the bands of the chloride (or of tin itself?) are made up of fine lines.

89 and 99. Tin Arc.

Material: arc between tin rods.

Impurities: Pb 4058 (lens), Na, Zn 4811, 4722, 4680 (in 99), Tl 5351 (lens), In 4511 (in 99).

Remarks. The following lines of triplets having the same vibration differences are visible: [3801, 3175, 3009], [3331, 2840, 2707], [2851 (lens)]; also the lines *5632*, *4525*, 3033, 2863/14, 2780/07. The line *5632* is doubled and reversed. 4524 shows ghosts in (99). Different metallic rods were used for the two halves of the spectrum, resulting in the stronger impurity lines in (99). When metallic rods are used for electrodes, as was done here, the ultra-violet of the arc is relatively weakened, perhaps on account of the low melting point of tin. A comparison of this spectrum with that of the spark shows great differences between the two.

90 and 100. Tin Spark.

Material: spark between metal points.

Impurities: air lines.

Correction: (100) + 1.

Remarks. Besides the arc lines mentioned under (89), a large number of spark lines appear, e. g. 6453, *5799*, *5589*, *5564*, 5333, 4859 (only at electrodes, lens), 4586 (only at electrodes, the upper part of the line being in consequence much stronger. The point below is caused by the astigmatism of the grating), 3599, 3352, 3284, 3262, 2659, 2632, 2463. Compare Nos. 257 and 258 in Chart XXVI as well as (89). The use of self-induction destroys the spark lines and produces a banded spectrum similar to (98).

Charts XI and XII.

101 and 111. Lead Arc.

Material: Arc between lead rods.

Impurity: Na.

Correction: (101) — 3.

Remarks. The triplets having the same vibration differences show the following lines: [4168, 2873, —], [4020, 2802, —], [3740, 2663 (lens)], [3672, —], [3573, —]. The lines *4058/62* are broadened, as is also *6002*. Other lines appear at 6237 (?), 6141 (?), 6061 (?), 6013 (?), 5190 (?), *3684*, *3640*, 2614. Compare with spark spectrum. As a result of the use of metal rods, the ultra-violet is relatively weak.

102 and 112. Lead Spark.

Material: spark between metallic poles.

Impurities: air lines.

Correction: (112) — 1.

Remarks. The lines belonging to triplets mentioned under (101) appear. The arc line 6002 is absent, as well as the lines 5006 and 5202, while 4058/62 are weakened. On the other band, numerous spark lines appear, the strongest at *4387* and *4245*, others at 5608, 5547, 5373, 5044, 3952, 3854, 3833, 3787, 3177, 3138, 3044. Compare No. 101 and No. 115.

115. Lead Spark.

Material: spark between metal poles, self-induction in circuit.

Remarks. The head spark offers an especially good example of the influence of discharge conditions on the spark spectrum. In the first place the air spectrum is entirely absent. Further, the spectrum stands midway between the spectra (102) and (101). The lines *4058/62* are the strongest, as in the arc. The spark lines 4387 and 4245 are present, but weak and appear only at the poles, as is also the case with the spark line 5608. Finally, there is a noteworthy contrast between the lines which as a rule appear only in the spark and those which are present also in the arc. While the latter (6002 (lens), 5202, 5006, 4058/62) are visible through the whole length of the spark, the spark lines (5608, 4387, 4245) appear only near the poles and form in consequence so-called "tips" in the spectrum if the slit is parallel to the axis of the spark. Compare in this connection the spectra of Mg, Sb, Bi (Nos. 29, 37, 106, 108). For lead flame compare (119) and (120).

103. Arsenic Arc.

Material: arsenic in carbon arc.

Impurities: Cy 4216, 3884, 3590, Ca, Al.

Correction: — 2.

Remarks. The following triplets with the same difference of vibration number appear: [3120, 3075, —], [3033, 2991, —], [2899, *2861*, —], [*2780*, 2745, —]; also the lines 2457, 2371, 2350 (lens). The arc spectrum of arsenic gives no lines above 3200. Compare Nos. 113, 104, 105.

113. Arsenic: Vacuum-tube.

Material: arsenic in vacuum-tube; heating box, condensed discharge.

Remarks. The spectrum is in most respects identical with that of the spark in air, but the lines are sharper than at atmospheric pressure. Spark lines appear at 6171, 6111 (lens), *5652*, *5559*, 5499, *5332*, 5231, 5108/05, 4986 (?), 4730 (?), 4707 (?), 4602 (?), 4548/44/40 (?). 4496, 4474 (?), 4467, 4459 (?), 4430 (?), 4425, 4350, 4240 (?) (lens).

104 and 114. Arsenic Spark.

Material: spark between arsenic electrodes in closed vessel.

Impurities: air lines.

Correction: (104) + 2.

Remarks. In addition to the lines 3120, 3033, 2899, 2861, 2780, 2745, 2493 (enhanced), 2457, 2381 (lens), 2371 (doubled, lens), 2350 (the last four enhanced), 2288 (lens), there appear a large number of spark lines, e. g. 6170 (lens), *5652*, *5559*, 5499, 5332, 5231, 5105, 4491 (diffuse), 4467 (diffuse), *4037*, 3949, 3931, *3923*, 2960. Compare Nos. 103 and 113.

105. Antimony Arc.

Material: antimony in carbon arc.

Impurities: Cy, Ca, Al.

Correction: — 1.

Remarks. Groups of lines with the same vibration differences appear at [4034, 3723], [3638, 3383, 2770, 2671], [*3233*, 3030, 2529], [2851, 2692 (lens)], [2719], [2653], [2615 (lens)], [2555 (lens)]. Other lines appear at *3268*, *2878*, 2598. Above 4034 antimony has only a few lines, all weak and diffuse. Compare No. 106.

106 and 116. Antimony Spark.

Material: spark between metallic poles.

Impurities: air lines.

Correction: + 1.

Remarks. The arc lines given under (105) appear, and besides these a large number of spark lines. The strongest of these lie at 6515 (lens), 6130, 6079, *6005*, 5910, 5894, 5639, 5569, 5465, 5178, 4950, 4879, 4592/07, *4352*, *4315*, 4265, 4219, 4195, *3598*, *3241*, *3041*, 2791, 2590 (lens). The lines show many differences in appearence. The arc lines and some of the strongest spark lines are equally strong throughout the breadth of the spectrum, i. e. they go from one electrode to the other. Others are stronger at the electrodes, e. g. 4352; while still others appear only as tips on the electrodes, e. g. 3567/59. Compare Nos. 115 and 108.

107 and 117. Bismuth Arc.

Material: metal in carbon arc.

Impurities: Cy 3884, Na.

Correction: (107) + 1.

Remarks. Groups of lines with the same vibration differences appear at [4493, 3511, 3077 (the weaker)], [4308, 3397, 2989], [*4122* (shows ghosts), 2893], [3888, 2781], [3596, 2938], [3405 (the weaker), 2810, 2525], [2864, 2431 (lens)], [2731]. In addition appear the lines 5552, *4723* (with three ghosts on each side), *3068* (reversed, lens), 3025, 2697, 2628, 2516, 2401.

108 and 118. Bismuth Spark.

Material: spark between metal poles.

Impurities: air lines, Pb 4387, 4245.

Correction: (108) + 1.

Remarks. The arc lines mentioned under (107) are visible, but are as a whole weaker than the spark lines. 4723 is weakened; 4308 is present (lens), but almost concealed by the new line 4302; 5552 is barely visible. Numerous spark lines now appear, among them 6058 (lens), 5940 (?), 5719, 5680 (?), 5451, 5271, *5209*, *5145*, *5125*, 5080, 4993, 4561, *4302*, *4260*, 4079, 3864/49/16, *3793*, 3696, 3655/14. As with lead, antimony etc., we find a number of spark lines in the bismuth spectrum which are not visible through the whole spark, like the arc lines and most of the spark lines, but only near the electrodes. Examples: 4325, 3614, 3486, 3474, 3451.

109. **Silicon Arc.**

Material: silica crystals in carbon arc.

Impurities: Cy 3884, heads of bands at 4216 and 3590.

Remarks. Silicon lines appear at [2507 (lens), 2514, 2516, 2519, 2524, 2529], *2882*, *3906*, 4103 (lens). In the less refrangible part there are no strong lines.

110. **Silicon Spark.**

Material: spark between silica crystals.

Impurities: air spectrum, 3995 (N) being strongest.

Correction: + 2.

Remarks. Of the lines mentioned under (109), 3906, 2882, as well as traces of the group at 2510 appear. In addition, new lines come at 4130/28, which are largely concealed by an air line. For the behavior of single lines, compare work of G. EBERHARD, Zeitschr. wiss. Photogr., 1, p. 346—355, 1903. A. DE GRAMONT, Chem. News *88*, p. 238, 1903.

119 and 120. **Lead Flame.**

Material: powdered lead peroxide falling through coalgas-oxygen flame.

Impurities: D lines.

Remarks. Besides the bands of lead or lead oxide (?) visible e. g. at 550 (lens) and seen to be made up of fine lines, the line spectrum shows lines at *4058*, 3684, 3640. The component 4062 seems to be absent; but this may result from the strong reversal.

Charts XIII and XIV.

121 and 131. **Niobium Arc.**

Material: niobic acid in carbon arc.

Impurities: Ti (strong), Cy, Y, Al, Fe.

Correction: The scale numbers in (121) are displaced 10 $\mu\mu$ to the right.
(131) — 2.

Remarks. The preparation had Ti as a strong impurity, so that the titanium bands appear. One sees also Y bands at 597, 613. Some of the stronger Nb lines appear at 2883, 2951, 3094, 3131, 3359, 3499, 3535/38/44/55/80, 3665/98, 3915/38, 4033, *4059*, *4080*, *4101*, 4124/37/40/53/64/68, 4206/15/18, 4301/27, 4524/47/73/82, 4607/30/72/75.

122 and 132. **Niobium Spark.**

Material: (122) niobic acid on carbon electrodes.
(132) same with self-induction in circuit.

Impurities: see (121); in (122) also air lines.

Correction: (22) + 2.

Remarks. Stronger niobium lines are at 2697, 2717, 2877/83, 2928/42/51, 3094, 3128/31/63/95, 3409, *3511*, 3688, 3717, *3819*, *4059*, 4164, 4573, 4630. Measurements are wanting for the less refrangible part of the spectrum.

123 and 133. Zirconium Arc.

Material: Zirconium oxide in carbon arc.

Impurities: Cy.

Correction: (123) above 400, + 2.

Remarks. The stronger Zr lines appear at 2970/86 (lens), 3012/30, 3111/66/91, 3234/73/79, 3306/35/88(d)/92, 3431/38/96, 3520/57/73, 3601/24/64/75/98, 3707/52/92, 3836/64/90/92, 3930/34/82, 4024/27/29 (d), 4055/73/81/91, 4109/22/49/67/88, 4202/39, 4241/68/82, 4341/48/67/95, 4421/32/71/97, 4507/36/42/53/55/76/91, 4634, *4688* (d), 4710/40/72, 4816, 5191, 5351/85, 6128/34/42, 6311/44 (lens). Compare the spark spectrum.

124 and 134. Zirconium Spark.

Material: (124) spark between carbon points with zirconium oxide.
(134) the same with self-induction in circuit.

Impurities: (124) air spectrum, Ca (H and K), C 2479, 2837, 4267.

Remarks. Lines of the spark spectrum are found e. g. at 2621 (lens), 2845, 2970 (d), 3055, 3107/82 (d), *3273/79*, 3306/36, 3338 (d), *3392*, *3438*, 3480/81/97/98, *3506* (d), 3543/57/73/77/88, 3612/15/75, *3698*, 3710/32/46/52/67, *3837*, 3958/91/99 (3995 is N line), 4030, *4149*, 4156/61/80, 4209/12, 4258 (lens), 4283, 4360/71/80, 4443/95/97, 4536/42/54/55/56/75, 4630/34, *4688*, 4710/40/72, 4816, *5192*, *5351*, *5386*, *6128/34/41*, 6311, 6345. The ground above 50 is filled with bands of the oxide (?), heads of these being visible e. g. at 562 and 555. The spark spectrum is essentially different from that of the arc and shows numerous lines which are either strengthened or peculiar to the spark. Above 65 only lines of the second order spectrum appear.

125 and 135. Yttrium Arc.

Material: yttrium sulphate (BETTENDORFF) in carbon arc.

Impurities: Cy, Na, Ca.

Correction: in (125), below 35 (— 2), from 35 to 38 (— 1).

Remarks. Examples of the stronger Y lines are 3200/03/17, 3242, 3328, 3496, 3549/85, *3601*, 3602/11/21/29/33/65, 3710/48/*75/77/89*, 3818/33, 3951/83, 4078/84, 4103/29/43, 4168/74/78, 4302/10/49/59/*75*/98, 4423/78/88, 4506/27, 4644/59/75/82, 4761/99, 4883, 4900, 5087, 5119/23, 5201/06, 5403/67, 5528, 5630/*63*, 5707, [6432/35/84] (probably second order). In addition, numerous bands (yttrium oxide?) are to be seen e. g. at 4475, 4650, 4818, [5972/88, 6004/20/36/54/81], [6132/49/65/82, 6200/18/37/53]. Compare No. 159.

126 and 136. Yttrium Spark.

Material: (126) spark between carbon points with yttrium sulphate.

(136) same with self-induction in circuit.

Impurities: (126) air spectrum, C (2479, 2837, 4267).
(136) Na.

Correction: below 30 (— 2.).

Remarks. The strongest lines and bands of the arc are to be seen (compare 125). Numerous differences may be noticed, however. For example, 2817, 2946, 3601, 4375 are strengthened, while 3496, 3585, 4527 and others are weakened.

127 and 137. Lanthanum Arc.

Material: lathanium sulphate (Bettendorff) in carbon arc.

Impurities: Cy, B (2497/98), Mg (2796, 2852), Hg (2967, 3022), Ca, Al (3082/93), Cu, Na, Fe.

Correction: (127) below 330 (— 2).

Remarks. The stronger La lines appear at 3105 (lens) /43/93, 3245/50/66, 3303/38/42, 3345/81, 3452, 3646/50, 3706/14/59/91/95, 3841/49 (lens) /86, 3916/22/29/*49*/89/96, 4032/43/78/87, 4123/42/52/87/92, 4204/*39*/70/96, 4334/54, 4427/*30*, 4523/26/59, 4575/80, 4606/14/20/56/64 (d, lens) /91/93, 4740(?)/43/49, 4787, 4804/09/24/61, 4900, *6421*(d)/71, 5000, 5115/23/84/88, 5234/71/91, 5302 (3 comp.), 5377/81, 4555, 5501, 5536, 5769/89/92/96, 5804, 5930, 6250/61/96, 6320/90/94, 6410. The lines above belong to the second order. Lanthanium bands (from the oxide?) are to be seen with heads at 4372, 4418, 5380, 5600, 5863.

128 and 138. Lanthanum Spark.

Material: (128) spark between carbon points with lanthanium sulphate.
(138) same with self-induction in circuit.

Impurities: (128) air spectrum, C (2479, 2837, 4267).

Remarks. Besides a number of the stronger arc lines (see above), spark lines appear, either new or enhanced, e. g. at *3172*, 3517, 4043; while many arc lines are weakened or absent.

129 and 139. Ytterbium Arc.

Material: ytterbium sulphate in carbon arc.

Impurities: Cy, Na, B (2497), Hg (3021, 3131), Ca.

Correction: (129) below 350 (— 2).

Remarks. The stronger Yb lines appear at 2892/95, 2900/12/63/71, 3006/31/78, *3290*, 3312/97, 3439/54, 3508, *3694*, *3988*, 4242, 4306, 4439, 4519, *4576*, 4684, 4726/87, 4936/94, 5335, *5477*, *5556*, 5720, 5982, 6002, 6221. The line 6578 belongs to the second order. At 4658 appears the head of a band shaded toward red (oxide?) which has not been previously recorded.

130 and 140. Ytterbium Spark.

Material: (130) spark between carbon points with ytterbium sulphate.
(140) same with self-induction in circuit.

Impurities: (130) air spectrum, C (2479, 2837, 4267), Cy.

Remarks. The Yb spark spectrum is very different from that of the arc, being richer in lines and the relative intensities of lines are quite different in the two spectra. Examples of lines enhanced or appearing only in the spark are 2643/66, 2804/19, 3555, 3561, 3620/70, while some arc lines (e. g. 4576) are absent. Compare No. 129.

Charts XV and XVI.

141 and 151. **Cerium Arc.**

Material: cerium nitrate (Rimbach) in carbon arc.

Impurities: Cy, Ca, C, Fe, Mg.

Remarks. The richness in lines of the cerium spectrum is such that only a partial resolution is possible. Many lines which appear simple to the eye are resolved by the lens into groups, each line of which may again have several components. Examples: 3942, 3953, 4150, 4246, 4563, 4715. Some more isolated lines are seen at 3423/26, 3710, 3802, 3999, 4013, 4187, 4460, 4528, 4628.

142 and 152. **Cerium Spark.**

Material: (142) spark between carbon points with cerium nitrate (Rimbach).
(152) same with self-induction in circuit.

Impurities: (142) air lines, Yb (e. g. 3057/58), La (e. g. 3072, 3517), C.

Remarks. In order to obtain only the stronger Ce lines, a short exposure was used. Below 355 Ce has only very weak lines. Some of the principal lines appear at 3032 (lens), 4134, 4138, 4460, 4523, *4527*, *4529* (see 152), *4540*, 4628, 5080, 5188 (lens, the middle of three lines), *5274*, *5331*, *5353*, 5394, 5410.

143 and 153. **Praseodymium Arc.**

Material: praseodymium sulphate (Muthmann) in carbon arc

Impurities: Cy, La (e. g. bands between 437 and 450), Ca, Na.

Remarks. Examples of stronger Pr lines are at 3909, 3949 (d), 3965, 3982, 4063, 4101/19, *4141/43*, *4223/26*, *4334*, *4429*, *5110*, 5174, *5220*, 5421.

144 and 154. **Praseodymium Spark.**

Material: (144) spark between carbon poles with praseodymium sulphate (Muthmann).
(154) same with self-induction in circuit.

Impurities: Cy, La, Ca, Na, C.

Remarks. The stronger Pr lines appear at 3877 (lens), 3909, 3982, 3990, 4009, 4055/57 (lens), 4063, *4101*, 4119, 4164, 4180, 4190, 4207, 4223, 4226, *4429*, 4510, *5110*, *5421*.

145 and 155. **Neodymium Arc.**

Material: neodymium sulphate (Muthmann) in carbon arc.

Impurity: Cy.

Remarks. Examples of the stronger Nd lines are seen at 3776/84, 3864 (lens), 3974 (d), *4012*, 4022 (4 comp.), 4041, *4061*, 4110/56, 4206, *4304*, *4447/52/63*, 4579, 5131/92, 5250/93, 5485.

146 and 156. Neodymium Spark.

Material: (146) spark between carbon points with neodymium sulphate (MUTHMANN).

(156) same with self-induction in circuit.

Impurities: air lines, Cy, C, Na.

Correction: (156) + 2.

Remarks. Compare the lines mentioned under (145). The line 4447 appears enhanced on account of concidence with the nitrogen lines 4447/23. Compare (156). In (156) the Cyanogen band 4216 appears, given when self-induction is used with carbon electrodes. Compare in this connection Chart XXVIII, No. 278.

147 and 157. Samarium Arc.

Material: samarium oxide (BETTENDORFF) in carbon arc.

Impurities: Cy, Na, Ca, Gd, Eu (?),

Remarks. Examples of Sm lines appear at 3255, 3307/21, 3403, 3568/93, 3671, 3983, 4065, 4119, 4237/57, 4319/91, *4425*, *4435* (d, lens), 4453/55, 4523, 4704/46/61, *4816*, *4884*, 5201/52/72/83, 5321/69, 5453/66, 5551.

148 and 158. Gadolinium Arc.

Material: gadolinium oxalate (DROSSBACH) in carbon arc.

Impurities: Cy, Y (bands 597, 613), Er, Yb.

Remarks. Examples of stronger lines: 2999, 3028/33/34/82, 3101, 3351/59/62, 3419/25/40, 3546/50, *3646*, 3654/56/71, 3713/20/44, 3894, 3917, *4037*, *4050*, *4064*, 4071/74, 4099, 4131/84, 4212/26/52/62/81, *4342*. The spectrum of Gd has not previously been investigated above 460.

149 and 159. Holmium Arc.

Material: erbium-holmium sulphate (BETTENDORFF) in carbon arc.

Impurities: Er, Y, Na, Cy.

Remarks. The preparation contained Er and much Y, though less than that used for (150) and (160). As a result, the complete spectra of these elements appear, including the Y bands at 597 and 613. Holmium lines are to be seen at 3446 (lens), 3485, 3516/24/32/39, 3646/95, *3786*, *3796*, 3837, 3874 (lens), *3891*, 3899, 3945/69, 4001, *4046* (2 comp.), 4104, 4212/21, 4309, 4450 (last two on 159). Some of the stronger erbium lines appear at 3617/93, 3730, 3831/96, 3906, 3937/39, 3973/75, 4008/13/21/56/60, 4088, 4143, 4151, 4420, 4607, 4676. Diffuse bands may be seen between 50 and 59, which show traces of resolution. They may belong to Ho (?) and give the arc an intense green color. Compare Nos. 150, 160, 161, 171.

150 and 160. Erbium Arc.

Material: erbium nitrate (BETTENDORFF) in carbon arc.

Impurities: Cy, Y, Yb, Ho, Tm.

Remarks. The preparation contained so much Y that the spectrum of this element predominates, and Y(?) bands are visible at 465, 471, 482, 502, 507, 613. Compare 159, 161, 181. As the lines of Y, Ho and Tm often lie so near together that they run into one another on the reproduction, a complete separation of the spectra is not possible, little being known of the visible portion for these spectra except in the case of Y and Yb. Erbium lines are found at 3231, 3313/73, 3499, 3617 (above), 3693 (left), 3831 (left), *3896*, *3906*, 3932/37/39 (lens), 3973/74, 4008, 4021, 4060, 4081/88, 4143/51, 4219, 4302, 4676.

Charts XVII and XVIII.

161 and 171. Erbium Spark.

Material: (161) spark between carbon points with erbium nitrate.
(171) same with self-induction in circuit.

Impurities: (161) air lines, Cy, C (*4267*, 2837, 2479), Y (e. g. 4375, 4178, 3789, 3775, 3710, 3601, 3328, 2817, 2415, 2367);
(171) Na, Y (bands at 600 and 620 also many lines) (e. g. 5663, 4900, 4883, 4855, 4423, 4375), Yb (e. g. 3290, 3694, 5477 (lens)), Ho(?), Tm.

Correction: (161) — 2.

Remarks. The preparation contained a great deal of yttrium, so that the strong yttrium lines and also the bands are all present (comp. 126 and 136), and the spectrum as a whole has the appearance of the Y spectrum. Erbium lines appear at 4873, 4675, 4420, 3907 (lens), 3831, 3693 (?), 3646 (lens). This list is uncertain, however, as all of the stronger Erbium lines are close to strong lines of Y, Pr, Sa, Yb. Those very close to Y lines are not mentioned, but the others are given, because the presence of Pr and Sa is rendered doubtful by the absence of their strongest lines. Compare Nos. 159, 158, 125.

162 and 172. Tungsten Arc.

Material: metal in carbon arc.

Impurities: Cy, Mo (e. g. 5507/33/71, 5633/50/89, 5752/92, 6030), Ca, Al.

Correction: (162) — 1; (172) + 1.

Remarks. The tungsten spectrum is exceedingly rich in lines, and also possesses diffuse bands. These circumstances combined produce the appearance of a continuous ground. Examples of stronger lines appear at 3965/79/83, 4009/15/46/70/75, 4102/18/*38*/*71* (d), 4241/44/60(d)/70, 4295, 4302, 4484, 4554, 4600, 4610/13, 6642, 4843, 4887, 4982, 5008, 5015, *5054* (reversed, lens), 5071 (doubled or reversed?), 5224, 5493, 5514, 5734, 5806, 6404, 6446, 6620, 6631. The arc spectrum is very different from that of the spark, especially in the ultra-violet.

163 and 173. Tungsten Spark.

Material: (163) spark between carbon poles with metal;
(173) same with self-induction in circuit.

Impurities: (163) air lines, Cy, Ca, C (4267, 2837, 2479), Mo (strong, e. g. 6030, 5570, 5530, 5507);
(173) Na, Mo.

Correction: (163) — 2.

Remarks. Examples of stronger Wo lines are found at 2702, 3078, 3402, 3614 (lens), 4071, 4295, 4303, *4843*, 5008, 5015, *5054*, *5224*, 5493, *5514*, 5734, 5806.

164 and 174. Thorium Arc.

Material: thorium nitrate in carbon arc.

Impurities: Cy, Ca, Mg [2852 (reversed, lens), 2803, 2796, 3091/93/97, 3833/38, 5173/84], Fe (4384).

Correction: (164) — 1.

Remarks. Stronger thorium lines appear at 3188, 3392 (lens), 3470, 3540, 3610/21/40/49, 3720/22/27, 4095, *4382/91*, *4865*, *4921*, *5539*. The whole ground is filled with the bands of thorium oxide (?), which show traces of resolution and have heads e. g. at 325, 329, 3346, 3930, 3988, 4020, *4115* (group), 4270, 4344, 4670, 504, 511, 591, 606, 614, 625, *638*, *640*. Nothing can be said concerning the numerous lines above 470, as measurements are lacking for this region. Compare the spark spectrum, which shows many differences from the arc.

165 and 175. Thorium Spark.

Material: (165) spark between carbon points with thorium nitrate:
(175) same with self-induction in circuit.

Impurities: (165) air lines (N 3995), C (4267, 2837, 2479), Mg (2852 (lens), 2803, 2798), Cy, Ca;
(175) Na, Mg (5173, 5184).

Correction: (165) — 1.

Remarks. Examples of stronger thorium lines appear at 2979, 3098, 3217 (lens), 3221, 3291, 3301, 3314 (lens), 3539, 3741 (lens), *4019*, 4069 (lens), *4382*, 4391, 4864, *4920*, 5375, *5539*. Traces of the bands of thorium oxide (?), which appear in the arc, are seen in the spark at 4920; but the line spectrum is relatively much stronger in spark than in arc.

166 and 176. Uranium Spark.

Material: spark between carbon points with uranium nitrate.

Impurities: air lines (e. g. groups at 46, 50, 55, 57, 59, 65), C (4267), Na.

Correction: (166) + 4.

Remarks. The spectrum of uranium is so rich in lines that with the resolution obtained here the appearance is that of a continuous spectrum. As in the arc spectrum the structure is further complicated by the diffuse bands stretching over the whole spectrum, only the spark spectrum is reproduced here, a partial resolution being obtained when very short exposure is used. Among the many thousands of uranium lines only a few are of medium intensity. Some of these are at 4090, 4242, 4270, 4342, *4544*, *5478*, *5483*, *5495*, *5528*, 5914.

167 and 177. Molybdenum Arc.

Material: Metal in carbon arc.

Impurities: Cy, Wo.

Remarks. Stronger lines of Mo are found at 3133, 3158, 3171, 3194, 3358, 3364, 3614, 3625, 3635, 3658/59 (lens), 3681, 3693/95 (lens), *3798*, 3864, *3903*, 4062, 4070, 4108, 4144, 4186/89 (lens), 4233, *4277*, 4289, *4292/93* (lens), *4326*, *4382*, 4412, 4435, 4442, 4450, 4458, 4468, 4475, 4627, 4708, 4730, 4760, 4820, 4831, 4868, 5171/73/74 (lens), 5238/41 (lens), 5361/64 (lens), *5507*, *5533*, *5571*, 5633, 5650, 5689, 5723, 5752, 5792, 5858, 5888, 6030. Weaker lines may be seen with the lens at 6353, 6422, 6616, 6649. In addition, the ground is filled with diffuse bands. Compare the spark spectrum.

168 and 178. Molybdenum Spark.

Material: (168) spark between carbon points with metal;
(178) same with self-induction in circuit.

Impurities: (168) air lines (e. g. 3995), Ca, Cy, C (2479);
(178) C [6584/79 (lens)].

Correction: (168) — 2.

Remarks. The arc lines of Mo given above are to be seen; but in the whole ultra-violet they are weaker than in the arc. Examples are 3133, 3798, 3903, 4292/93 (lens), 4382, 4412. Other lines are strengthened, as 3635, *3688*, *3693*, 3703, 3782, 3786 and others. Still others appear only as spark lines, e. g. 3651/53 (lens), 3832, 3962, 4120 (lens), 4279, 4311, 4378. Finally, the whole ultra-violet part below 360 offers an example of intensity changes and appearance of new lines in the transition from arc to spark. Some of the strongest lines in this region lie at 2661, 2673, 2684, 2816, 3088. Note the difference in the intensity of Ca lines, which appear from impurities. While H and K are strong, 4227 is weak. The reverse is true in the arc spectrum (167).

169 and 179. Titanium Arc.

Material: titanium-ammonium fluorite in carbon arc.

Impurities: Na (3303), Ca (4227, 3934), K (4044/47).

Remarks. Stronger Ti lines are seen at 3187, 3192, 3200, 3342, 3355/61/72/78 (Ω_1, Exner and Haschek), 3386/88, 3536, 3730, 3741, 3753, 3930 (lens), 3948/49 (lens), *3982*, *3990*, *3999*, 4009, group 425—428 (lens), 4426/27 (lens), 4450/51/54/56/58, *4513/18/23/28/35/45/49/53/56* (characteristic group, 4535 having 6 comp. 3 visible), 4657, 4668, 4675, 4682, *4990*, 5000, 5007, *5014*/16/20/23/26 (lens), *5036*/38/40, 5065, 5211, 5689 (lens). Above 40 the ground is filled with titanium bands (oxide?)

edges of which are to be seen at 435, 458, 463, 466, 476, 480, 495, 517, 545, 560. The Na lines, appearing in (179) from impurities, are broadened and reversed.

170 and 180. Titanium Spark.

Material: (170) spark between carbon points with titanium-ammonium fluorite;
(180) same with self-induction in circuit.

Impurities: air lines (in 170), C, Cy, Ca (H and K), Na, O (4070/72/76).

Correction: (170) — 2.

Remarks. The spark spectrum of Ti is very different from that of the arc. Compare (169). While most of the lines are common to both [e. g. 3536, 3982, 3990, 3999 (lens; near the strong N line 3995), strong group at 535], the intensities are in most cases changed. Some are weaker in the spark (e. g. group 395—397, some lines of group 430); others are strengthened (e. g. most lines below 340, 3662, *3685*, 3706, 3742, 4469, *4550*); still others appear only in spark (e. g. numerous lines below 340, group 351. *3759/62* (lens), 4164, 4399, 4411, 4444, 4501, *4572* etc.). Among other Ti lines are those at 2564 (lens), 2747/52 (lens), 2818, 2828, 2985, 3017, 3072/73/75/78 (lens), 3162/63/69, 3191, 3203, 3235/36/39/40/42, *3350*, *3361*, *3373*, 3660/62, 3901, 4290/94, 4417/18, 4469/88, 4564/90, 4630/40/45/50, 4981/91, 5001/07/14/36, 5174, 5193, 5211, 5513, 5663, 5676, 5680, 5690. Compare No. 169.

* * *

Charts XIX and XX.

181 and 191. Vanadium Arc.

Material: vanadium chlorate in carbon arc.

Impurities: Na, Cy, Ca, Mn.

Remarks. The arc spectrum of Va is very different from the spark spectrum. Among the numerous lines, some of the stronger are at 3102/11/18/25/26/30/33 (lens), 3183/84/86/88/91 (lens), 3298, 3376, 3517/20 (lens), 3545, 3687/88/90/92/95/96 (lens), 3704, 3856, 3875, 3991/93/99 (lens), 4051, group between *4091* and *4735*, notably 4132/35, 4210, 4269/70/72 (lens), 4330/33, group between 4380 and 4480, notably *4407/08/09*, 4577/79/81, 4587, 4620, 4671, 4766, 4776, 4852, 4926, *5699*, 5727, *6040*, *6090*, 6120, 6243. The ground is filled with bands (vanadium oxide?), heads of which are visible e. g. at 577, 547, 527. Compare No. 182.

182 and 192. Vanadium Spark.

Material: spark between carbon points with vanadium chlorate.

Impurities: (182) air lines, C, Mn.

Correction: (182) + 11.

Remarks. The spark spectrum contains almost all lines of the arc, but with intensity altered throughout so that characteristic arc groups, as 3700, are hardly recognizable. Examples of weakened arc lines are (note correction) 4489/91/96, 4620, of strengthened arc lines 3545, 3557. Other strong spark lines are 2529, 2688, 2766, 2769, 2810, 2892/93/96, 2909, 2924/25 (lens), 2969, 2972/74/76 (lens), 3001, *3093*, *3102*, *3111*, 3188, 3191, 3268/71/76, 3457, *3517/31/45/57*, 3590/92/93 (lens), 3716, 3728, 3746, 3771, 3968, 3974, 4006, 4024, 4036, 4184, 4379/85/90/95 (also arc), 4401/09/17, 4461/63. In the visible portion the spectrum is essentially identical with that of the arc (compare No. 181) and the Va bands are to be found also in the spark.

183 and 193. Chromium Arc.

Material: metal in carbon arc.

Impurities: Na, Cy.

Correction: (183) — 2.

Remarks. Bands appear in the Cr arc (oxide?), especially in the region of shorter wave-length, filling the ground of the spectrum and showing edges e. g. at 605 and 557. Among the numerous lines of Cr the strongest are found at 2781, 2987 (lens), 3054, 3368 (lens), *3579*, *3594*, *3605*, 3744, 3749, 3758, 3768, 3841, 3964, 3970, 4154, *4255*, *4275*, *4290*, 4352, 4497 (lens), 4601, 4646, 4652, 4708, 4718, 4922, *5205/06/09* (lens), 5247, 5264/66 (lens), 5297/98 (lens), 5329, 5346/49, 5410, 5791. Also at 633 and 636 lines are to be seen whose connection with chromium is uncertain.

184 and 194. Chromium Spark.

Material: spark between metal points.

Impurities: air lines (at 500), C.

Correction: (184) — 2, (194) — 1.

Remarks. The spark spectrum of Cr is very different from the arc. The ultra-violet below 350 is notably strengthened, many new lines appearing. The visible part is weakened. Most of the lines of the arc are also visible in the spark (e. g. the triplets at 357, 426, 520); but others are lacking (e. g. 3758, 3768), while many are strengthened or appear only in the spark. Some of the strongest spark lines an found at 2538 (lens), 2677, 2699 (3 lines together), 2720 (lens), 2831/36/43, 2980 (lens), 3041/50, 3119/20/25/32 (lens), 3181/97, 3269, *3368*, 3409/21/23 (lens), 3579, 3585 (2 lines together), 3594, 3604/05 (lens), 3744 (2 lines together), 3749, 3984, *4255/75/90* (compare arc), *4559/89*, 4651/52, 4718, 4922, 5205/06/09, 5275/98, 5410. The greater part of these lines an present also in the arc spectrum, but much weaker. Above 5400, other weak lines appear between the diffuse air lines.

185 and 195. Manganese Arc.

Material: (185) spark between carbon points with manganese chloride;
(195) same with self-induction in circuit.

Impurities: Cy 3884, Co, Ni, Na, Fe.

Correction: (195) + 1.

Remarks. As with Va, Cr etc, bands, perhaps belonging to the oxide, are found with the lines of the arc spectrum. Heads of bands are to be seen e. g. at 638, 620, 585, 558, 536, 515. The diffuse strips in the ultra-violet at 280, 325 are seen with the lens to be caused by densely grouped lines. Some regularly constructed triplets are found in the Mn spectrum: of the first subseries at [3570, 3548, 3532], [2940, 2926, 2915], [2726, 2713, 2704 (lens)] ($n = 4, 5, 6$); of the second subseries at [4824, 4784, 4754], [3179, 3161, 3148 (lens)] ($n = 3, 4$). Stronger Mn lines are found at 2576, 2596, at 2800 a diffuse group with two reversed lines, 2933, 2949, 3044 (diffuse), 3054 (lens), 3790, 3824 (2 comps.), 3840/41 (lens), *4031/33/35* (broadened and run together), 4042, 4084 (2 comps.), 4235/58/66, 4375, *4415*, 4437, strong group at 446, 4490, 4502, 4762, 4766, 5118, 5299, *5341*, 5378, 5389, 5471, 5481, 5538, *6014/17/22*. Compare No. 186.

186 and 196. Manganese Spark.

Material: (186) spark between carbon points with manganese chloride;
(196) same with self-induction in circuit.
Impurities: (186) air lines, C (2478), Cy, Ca (4425, 4436, H, K).
Correction: (186) — 2, (196) — 1.

Remarks. The spark spectrum of Mn also differs greatly from that of the arc. The ultra-violet is strengthened, whole groups of new lines appearing in this region. Many arc lines are weakened (e. g. group at 323, 4437/90, 4502, 4709/28/39), others again are enhanced (e. g. group 345—350). Of enhanced or "spark" lines the following examples may be given (arc lines which remain visible in the spark are distinguished by an asterisk): 2428/39/53, *2576/94*, *2606*, 2795*, 2870 (lens), 2880, *2933/39/49*, 3020, 3228/31 (lens), *3442/60*, 3474/83/89/96/97 (lens), 3532/48/70* (several comps.), 3824 (2 comps.), 3830, 4018*, *4031/33/34/35** (lens), 4235, 4452/55/58/62/65*, 4754/62/66/84*, 4824*, 5341/77, 5422, *6014/17/22*. — 5341 is very weak unless self-induction is used.

95 (Chart X). Manganese Flame.

Material: chloride on small carbon rods in coalgas-oxygen flame.
Impurities: Ca 4227.

Remarks. The following Mn lines appear: *4031/34/35*, 4754/84, 4824 (lens, series lines), 5395, 5432. Bands also appear, as in the arc (from oxide?), of which those at 56 are resolved into lines (lens).

187 and 197. Iron Arc.

Material: Arc between rods of ordinary wrought iron.
Impurities: Al, Cu, Mn.

Remarks. With a spectrum so rich in lines as iron, it is well always to use the lens in examination of details. Some of the strongest lines appear at 2398, 2404/11, 2501, 2576, 2606/07, 2719/21, 2895, 2929, 2937, 2994, *3021* (2 comps.), 3067, 3100 (4 comps.), 3126, 3266, 3306 (2 comps.), *3441*, 3466, 3526 (2 comps.), *3566/70*, 3581/86, 3619/32, 3758/60/64/67, 3821/26/28, 3834/60, 3928/30, 3969, *4005/46/64/72*, 4132/44, 4261, *4272*, 4308, 4326, *4384*, 4405/15, 4528, 4679/91, 4736, 4860, 4919/21/24, *5041*, *5193/95*, 5227/33, 5384/97, 5404/06, *5587*, *5616*, *5863*, *6066*, *6137*, *6192*, 6301, 6412/31, *6495*. The continuous ground in the region about 60 arises from the bands of iron oxide, here not resolved. Compare Nos. 88, 251, 77.

188 and 198. Iron Spark.

Material: spark between metal poles.

Impurities: (188) air lines, Ca (H, K), C.

Correction: (188) + 2.

Remarks. The spark spectrum of iron is very different from the arc spectrum. While the latter is stronger in the visible portion, the spark possesses the greater intensity in the ultraviolet, and some new lines appear, e.g. 4523/20/15/08. Many arc lines are strengthened, (e. g. 2986, 4550/84, 4924, 5018); others are weakened (e. g. 3021, 3100). A number of the stronger lines (for the most part enhanced lines) are found at 2338, 2344, 2382, 2399, 2405/13, 2586/98, 2600 (lens), *2743/47/49/56*, 2841, 3154, 3228, 3441, *3570*, *3581*, 3585 (2 comps.), 3632, 3735, 3748/49 (each 2 comps.), 3816/20, 3841, *4046/64/72*, 4132, 4250 (2 comps.), 4261/72, 4308/26/84, *4404/15*, 4476/82/94, 4529, *4860/71/91*. 4919/20/24 (lens), 4957, 5139/67/69 (lens), 5227/33/70, 5324/28, 5370, 5445. Compare Nos. 187 and 251. In (198) the air lines are relatively weak, because a magnified image of the spark was projected and only the outer part fell on the slit.

251 (Chart XXVI). Iron Spark.

Material: spark between metal poles, self-induction in circuit.

Correction: + 3.

Remarks. The self-induction here used was so large that the lines of the air spectrum are quite blotted out. Under these conditions the intensities of the iron lines are changed in the direction of an approach to the arc spectrum. The lines between 50 and 55 become stronger, the intensities of most of the lines lie between that of the ordinary condensed spark and the arc (e. g. 5659 (lens), 5616, 5587, 5237). Some lines appear which are absent in the usual spark (e. g. 5193), while others show the opposite behavior (e. g. 5195, 4584/50/23/20/16/08; and still others are found in the arc which are absent in the spark with self-induction (e. g. 4401, 4615/30, 5195). Compare Nos. 187, 188, 77. It is also to be noticed that all lines gain in sharpness when self-induction is used.

77 (Chart III). Iron Flame.

Material: iron chloride on small carbon rods in coalgas-oxygen flame.

Impurities: Ca 4227, K 4044/47, Mn 4030/33/35.

Remarks. Diffuse bands appear with maxima at 56 (iron oxide?), a continuous ground between 420 and 475 and a number of iron lines (lens), examples of which are at 3720/35/37/46/50, 3820/25/26, *3860/79/86*, 3896/99, 3923/28/30, 4046, 4272, 4326/76, *4384*, *4405/15*, 4461. The absence of many strong arc lines, as 4063, 4308 and others, is noticeable, while the lines 3923, 4376, 4461 are relatively strong. All lines with the exception of the three last named are strong lines in the arc. Compare Nos. 187, 188, 251.

189 and 199. Cobalt Arc.

Material: Cobalt chloride in carbon arc.

Impurities. Cy (3590, 3884, 4216), Na.

Correction: (189) — 2.

Remarks. The ultra-violet part of the Co arc spectrum is relatively weak. Examples of stronger lines are found at 3405/10/13, *3444*, 3450 (2 comps.), 3454, *3474*, *3503*, 3507, *3530*, 3570/75/85/87, 3662/77, *3746*, *3894*, 3953, *3995*, 3998, 4045/93, *4111/19/22*, 4191, 4252, 4340, 4467/70, *4531/34*, 4566/82, 4630/63/83, 4750, *4814/40/68*, 4929, 5213/67, 5343/70, *5484*, 5990, 6081/91, 6179, 6231/81, 6450/54. Compare Nos. 190 and 36.

190 and 200. Cobalt Spark.

Material: (190) spark between metal poles*;
(200) same with self-induction in circuit.

Impurities: (190) Air spectrum, Cu 3247/74.

Remarks. The spark spectrum of cobalt differs greatly from that of the arc. While the spark shows fewer lines than the arc in the visible part, the reverse is true in the ultra-violet. The greater part of the lines are common to both spectra but many relative differences exist. Examples of stronger lines are 2286, 2308/62/64/86/89, 2408/64/67, 2507/24/29/30/60/80/82/87 (the last are enhanced), 2614/64/67, 2707, 2871 (spark line), 2955 (spark line), *3388*, 3454, *3503*, 3570/80/87, 3621 (spark line), 3750/55 (3 comps.), 3846/73/74/94, *4119/22*, *4531*, 4582, 4630, 4814/41/68. As examples of arc lines which are absent in the spark, we have 4477, 4550. Compare Nos. 189 and 36.

36 (Chart IV). Cobalt Flame.

Material: Cobalt chloride on small carbon rods in coalgas-oxygen flame.

Impurities: Ca 4227, K 4044/47.

Remarks. Above 420 a continuous spectrum (cobalt oxide bands?) appears, with a minimum at 530 enhanced by the photographic action. Stronger cobalt lines appear at 3444 (lens), 3503/75, 3842/46, *3874*, 3883/95, 3910/79/95/98, 4021/27/45 (lens), 4093, *4111/19/21*, 4191, 4252/86. Compare Nos. 189 and 190.

Charts XXI and XXII.

201 and 211. Nickel Arc.

Material: metal in carbon arc.

Impurities: Cy, Na, Mn (2795/98, 2801, 4030/33/35), Mg 2803, 2852 (lens), Co (4119/21, 4046, 3998), Ca, Al, Fe [e. g. 4384 (lens)].

Correction: (201) — 1.

Remarks. Stronger nickel lines are found at 2821, 2907/44/82/84/93/95, *3003/04* (lens), 3012/38/51/54/58, 3102 (d), *3134*, 3233/35 (lens), 3381/91/93, *3414/15* (lens), *3493*,

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*) Electrodes of Co, Ni, Pd, Pt, Ir and Au were lent to us by Dr. A. PFLÜGER, of Bonn, being used by him in his researches with the thermopile in extreme ultra-violet. We take pleasure in expressing our thanks for his kindness in placing these materials at our disposal.

3525, 3567, *3620*, 3689, 3776/84, 3807/32/59, 4332, 4384 (lens, to right), *4402/59/63/71*, 4593, 4601/05, *4649*, *4715/16*. *4856/66*, 4874, 4905/80/84, 5018/36, *5080/81/84* (lens), 5100/15, *5477*, *5893*, *6177*. The line 5893 lies midway between the D lines of sodium, in the same way that appears as an absorption line in the solar spectrum.

202 and 212. Nickel Spark.

Material: (202) spark between metal electrodes;
(212) same with self-induction in circuit.

Impurities: (202) air spectrum;
(212) negative pole nitrogen bands at 428 and 391 (compare No. 233).

Correction: (202) + 2, (212) — 1.

Remarks. A number of the stronger lines are common to arc and spark spectra. Compare the list given under [201]. Numerous differences appear, however, for example the following lines are enhanced in the spark: 2395, 2416/38, 2511, 3859, 4307, 4402/59/63/71, 4593, 5477. The line 4067 appears in the spark only. Other lines are weakened or absent in the spark, as 3003, 4520/52/81, 4685, 4701/04, 4829/40/52/58/71, 4905/12/14/36/37, 4954/72/88, 5893. A number of minor differences are also to be noted when the spark is used with and without self-induction.

203 and 213. Ruthenium Arc.

Material: ruthenium oxyhydrate (Bettendorff) in carbon arc.

Impurities: Cy, Ca, Na, Fe, K [compare the triplet 4044/46/47 (lens)].

Correction: (203) — 1, (213) + 2.

Remarks. Examples of Ru lines are found at 3254, 3317, 3418/29, 3437, 3499, 3515, 3593/96, 3600, 3635/62, *3727/28*, 3786/91, 3800/09/32, 3979/85, 4081, 4113 (d), 4144/46, 4200 (d), 4206/12, 4295/96/98 (lens), 4372, 4410, 4555, 4585, 4645/48/54, 4710/56/58, 4816/69/96, 4903/21, 5057, 5171, 5333/34/36 (lens), *5401*, *5455/56*, 5480/85, *5511/60*, *5636*, 5699. Still other lines appear as far as 6875, e. g. 6440/64, 6549, 6680/84, 6709/37/86/95, 6836/57/65. The last of these probably belong to the second order spectrum.

204 and 214. Rhodium Arc.

Material: rhodium-ammonium chloride (Bettendorff) in carbon arc.

Impurities: Cy, Ca, Na.

Correction: (204) — 1, (214) + 1.

Remarks. Examples of rhodium lines appear at 3191 (lens), 3263/81/84, 3323/97, *3435*, 3503/28/83/96/97 (lens), 3658/91/93/96/98, 3701, 3799, 3857, 3959, 4129/35, 4211/89, *4375*, 4529/69, 4675, 4745, 4843/44/52 (lens), 4964, 5090, 5156/57/58 (lens), 5193, *5237/55/57*, 5391, 5404/25/26, 5535/45, *5600*/09/87/5807/32, *5984*. Above these are numerous other lines, some of which belong to the second order, e. g. 6646 = 3323 of first order, 6795 = 3397, 6870 = 3435 etc.

205 and 215. Palladium Arc.

Material: metal in carbon arc.

Impurities: Cy, Cu (3247/74), K, Fe, Pb (4020/58?).

Correction: (205) — 2, (215) + 1.

Remarks. As compared with the other elements of the platinum group, the lines of palladium are few, but strong. Examples of Pd lines are at 2442, 2763, 2923, 3003/28/65, 3114, *3243*/52/59/87, 3302/73, *3405*, 3421/34/42/61/81/90, *3517*/53/71, *3610/35*, 3690, 3719/99, 3832/94, 3959, 4101/71, *4213*/68, 4345/51, 4407/74, 4516, 4788, 4818, 4876, 5111/15/17, 5164, 5235, *5296*, 5395, *5543/47*, 5620/70/95, 5737/40, 6131/71/76/89. The lines of still greater wave-length belong to the second order spectrum.

206 and 216. Palladium Spark.

Material: (206) spark between metallic poles;
(216) same with self-induction in circuit.

Impurities: (206) air (3330/32, 3437, 3750, 3919/95), Ca.

Correction: (206) above 320 (— 3), below 320 (— 1); (216) — 1.

Remarks. The arc and spark have in common a large number of easily recognized lines, given for the most part under (205). There are, however, many large differences in relative intensity. As examples, the following lines are enhanced or peculiar to the spark: 2297 (lens), 2338/51/62, 2447/48, 2487/89/90, 2552/66, 2628/36, 2855, 2981, 3000/32, 3268, 3919. Some arc lines are absent in the spark, e. g. 3383, 4407, 4516, 4541, and others, as 3407 are weakened. The lines above 67 belong to the second order spectrum.

207 and 217. Osmium Arc.

Material: osmium-iridium in carbon arc.

Impurities: Cy, Ir (comp. 208 and 218), Ru (strong), Ca, Pb, Cr.

Correction: (207) — 2, (217) + 2.

Remarks. As is was necessary to use an alloy of the metal with Ir, the spectra of the two metals are mixed. Examples of osmium lines are those at 3232, 3428, 3640, 3977, 4067, 4136, 4212, *4421*, 4261, 4312, 4551, 4617/64, 4794, 5203 (left from the Cr lines).

208. Iridium Spark (230—480).

Material: spark between metallic electrodes (comp. 201), with self-induction in circuit.

Impurities: N (negative bands) 3912, Ca.

Correction: (— 1).

Remarks. Examples of stronger Ir lines appear at 2694, 2801/25, 2925, 3069 (d), 3101/21/33, 3221, 3437/49, 3514/74, 3629/75/93 (spark lines), 3747, 3800 (?), 3902, 3916/76, 4020/70, 4268, 4312, 4400/26, 4617.

218. Iridium Arc (440—690).

Material: iridium salammoniak (Bettendorff) in carbon arc.

Impurities: Cy, C (bands), Na.

Correction: + 1.

Remarks. The iridium compound being at once dissociated in the arc, a small metallic regulus was formed which vaporized very slowly. In consequence, the carbon bands are given strongly in the photograph, the whole ground being filled with their fine lines. Iridium lines may be seen at 4426, 4617, 4729/78/96, *4938* (d), 4971, 5000/03/09, 5178, 5239, 5341, *5365*, *5450/55*, 5620/26, 5894 (between the D lines), 6111.

209 and 219. Platinum Arc.

Material: metal in carbon arc.
Impurities: Cy, C, Na, Pd, Ru, Rh.
Correction: (209) — 2.

Remarks. Examples of stronger Pb lines are 2628/47/51/60, 2703/06/19/34, *2830*, 2930, 2998, 3037/43/65, 3101/40, 3204, 3302/24, 3408, 3630 (d, lens), 3700, 3967, 4119, 4443/46 .4499, 4553, 4641/58/84, 4831/54/79, 5033/44/60, *5228*, *5301*, 5369/91, 5476/79, 5514/26, 5699, 5763, 5840/45/61, 5979/83, 6024/26, 6319/27, 6523 (lens).

210, 220 and 238 (Chart XXIV). Platinum Spark.

Material: (210) spark between metal poles.
(220) and (238) same with self-induction in circuit.
Impurities: (210) air spectrum, (239) N bands (neg. pole), Ca (3933/68).
Correction: (238) + 1, (220) — 2.

Remarks. The most important types of spark spectra are given, in consideration of the frequen use of platinum electrodes to carry other substances. The stronger arc lines are found in (238) at 2628/60 (lens), 2703/06/19/34, 2830, 2930/98, 3042/64, etc. (compare 209), and in corresponding places in Nos. 210 and 220. In addition the spark spectra differ greatly from that of the arc and among themselves. For example, the arc lines 4446, 4640/84, 4953, 5034/44/68, 5194. The spark without self-induction gives a stronger ultra-violet portion.

Charts XXIII and XXIV.

221 and 231. Copper Arc.

Material: arc between metal rods.
Impurities: Zn (4650, 4722, 4811).
Correction: (221) + 2.

Remarks. Examples of strong Cu lines are found at 2294, 2302 (lens), 2393, 2406, 2442, *2619*, 2767/69, 2825, 2883, 2961, 3036/64, 3109/26/29/43/47, 3208, *3247/74*, (r, br, lens), 3308/65, 3484, 3512, 3599, 3602, 3654/88 (br. toward red), 3701, 3772, 3861, *4023/63* (dif.), 4178, 4249, 4275, 4378, 4416, 4480, 4508/10, 4531/40/87, 4651/75, 4705, *5106/53*, *5218*, 5220 (lens), 5293, *5700/82*, 6362 (?), also copper oxide bands (?) at 6150/60. Pairs of the first subseries lie at [5220/18, 5153], [4064, 4023], [3689, 3655] ($n = 4, 5, 6$); a pair with lines broadened toward the violet (corresponding to lines in the spectra of the alkali metals: possibly, as we found to be the case there, the beginning of a series) at 4059/16; pairs of the second subseries at [4531, 4480], [3862, 3825] (n = 4, 5); strong pairs with the same vibration difference at [5782, 5700], [3274, 3247]. Concerning the behavior of the single lines under the most diverse conditions of arc and spark compare A. S. King, Astrophys. Journ. *20*, p. 21—40, 1904. Flame lines appear at 5700, 5106. Compare Nos. 222, 233.

222 and 232. Copper Spark.

Material: (222) spark between metal electrodes;
(232) same with self-induction in circuit.

Impurities: (222) air spectrum.

Correction: (222) — 2.

Remarks. The copper spectrum is dependent to an unusual degree on the conditions of production (compare above), through a large number of the stronger lines are common to arc and spark. In the spark numerous arc lines are weakened or absent, as 5555/36, 5432, 5392, 5076, 4698/75/43, 4259/42, 4123, 3825, 3689/85/55, 3094, 2618, 2394. Other lines appear only in the spark or are stronger than in the arc, e. g. 2243/47 (lens), 2276, 2370, 2507/45, 2600/90, 2701/03/14/19/22, 2770, 2838/78 (lens), 3109/26/29/47, 3236/43 (lens). Compare (233). Numerous examples of reversal and unsymmetrical broadening are found in the copper spectrum.

233. Copper Spark.

Material: spark between metal electrodes, self-induction in circuit, electrodes heated.

Remarks. Together with the strongest copper lines, the negative pole bands of nitrogen appear at 3577, 3912, 4278, 4555. These are composed of alternately strong and weak lines and appear especially strong with electrodes of Zn, Cu, Al, Ag. Compare Pt (238) and Ni (212). The bands appear also in the very weak arc between copper electrodes. A number of copper lines, strong in the condensed spark and appearing faintly in the arc, appear with self-induction only near the poles, examples being 3109/26 3290, 3308/65, 3450/76/84, 3599, 3602/14/21, 4416. The intensity of these lines is reduced in the arc when a very weak current is used, and restored when the weak arc is continually interrupted, or in the spark when a hydrogen atmosphere is used.

223. Copper Flame.

Material: powdered copper in coalgas-oxygen flame.

Impurities: Pb (4058).

Remarks. Two flame lines of Cu are found at 5106 and 5700. Between 517 and 576 lie a number of diffuse bands (copper oxide?). Stretching upward from 4279 is a band (Cu?) composed of several series of fine lines (lens).

224 and 234. Silver Arc.

Material: metal in carbon arc.

Impurities: Cy, Na, Ca, Pb (3640).

Correction: (224) — 2.

Remarks. Line pairs belonging to the first subseries are seen at [5472/66, 5209], [4212, 4055], [3811, 3682], [3624, 3585?] (n = 4, 5, 6, 7); pairs of the second subseries at [4669, 4476], [3982, 3841], [3710] (n = 4, 5, 6). An isolated pair lies at [*3383*, *3281*] (principal series?), and in addition isolated lines at 6273 (?), 4213, 3502, 3469, 3130, 2825, 2722 (lens), 2375, 2310 (lens). The spectrum offers good examples of broadening and reversal phenomena. In regard to the last, compare (4212, 4055) with (3383, 3281).

225 and 235. Silver Spark.

Material: (225) spark between metal poles;
(235) same with self-induction in circuit.

Impurities: (225) air spectrum.

Remarks. The series lines of the arc spectrum appear, but relatively weak, so that only the pairs of higher number remain visible. Numerous lines appear which are absent in the arc, e. g. 4349, 2800, 2768/57/12, 2474/48/38/13/11 (lens), 2359/58/31/25/20/17 (lens).

226 and 236. Gold Arc.

Material: gold iodide in carbon arc.

Impurities: Cy, Ag (3281, 3383), Na.

Correction: (226) below 300 (— 2).

Remarks. Lines of isolated pairs are visible at [6278, 5064] (first subseries?) and [*2676*]. Other gold lines are at 5957 (lens), *5838*, 5656, 5231 (Pt?), 5065, 4811, *4793*, 4607, 4488, 4437 (lens), 4315, 4242 (lens), 4065, 4041, 3909 (lens), 3123, 3029 (lens), 2748.

227, 237 and 228. Gold Spark.

Material: (227) spark between metal electrodes;
(228 and 237) same with self-induction in circuit.

Impurities: Ag (3383, 3281), Cu (3247/74), air spectrum (in 227).

Remarks. All of the stronger arc lines are visible, and (228) shows in addition lines at 3898, 3270, 3067, 2428. (227) shows also the lines 3586 and 2813, which are weakened by self-induction.

229 and 239. Nitrogen Line Spectrum.

Material: (229) Nitrogen in vacuum tube at 1 mm pressure, capacity and spark gap in circuit;
(239) spark between Al electrodes in air.

Impurities: (229) Cy (3884); (239) Al (5724, 5697).

Remarks. Nitrogen lines are visible in (229), for example, at 3839, 3940 (dif), 3956, *3995*, 4026/35/41 (dif), 4043 (?)/57, 4176/80, 4229/*37*/*42*/66, 4348, 4426/33/*47*, 4530, 4602/07/14/22/*31*/43, 5003/06 (lens) 5572 (?)/76/86. Edges of the stronger bands of the positive pole are seen at 338, 358, 375, 380 (compare No 229), given by the discharge in the wider part of the tube. The spectra in (229) and (239) are somewhat different, the nitrogen lines in the letter being more broadened, with some differences in relative intensity, and oxygen lines show in this. Besides the lines given above which are common to both photographs, (239) shows nitrogen lines at 4675, 4780/88, *5003/06*/08, 5666/76/*79*/86, 5811, *5930/33/43*, 6245/49, oxygen lines at 4317/20/46/48/67, 4591/96, *4642/49*, 4662, these belonging to the so-called "elementary" line spectrum of oxygen. The line spectrum of air appears in all spark spectra when no self-induction is in circuit and a spark of medium length is used. The absolute and relative intensity of single air lines depends much on the kind of electrodes used. The air spectrum is strong with electrodes of C, Cu, Ag, Au, Pt, Al, weak with Cd and Mg. The various spark spectra in the atlas offer many examples of this effect. Compare also Nos. 267 and 277 and the work of G. A. Hemsalech, Recherches sur les spectres d'étincelles, Dissertation, Paris 1901, A. Hermann, p. 114—123.

230 and 240. Nitrogen Band Spectrum.

Material: Nitrogen at 4 mm pressure in vacuum tube, without capacity.

Impurities: Na (D lines), H (6563, 4861, 4341).

Remarks. The positive pole band spectrum of N appears here, given by the light of the positive column. The bands fall into three groups. The first group, in the ultraviolet and not visible in the photograph, is generally ascribed to NO. The second group lies between 28 and 50, the third still higher. All of the bands are made up of fine lines (lens). The edges of the bands are in most cases distinct, but the following are not so easily recognized: 4574, 4648, 4666 (No. 240), 4723, 4813, 5340, 5614, 5755, 5804, 5854, 5906, 5959, 6013, 6069. For the second (negative pole) band spectrum of N, the structure of which is entirely different, compare No. 233.

Charts XXV and XXVI.

241. Phosphorus Arc.

Material: phosphorus pentoxide in carbon arc.

Impurities: Cy, Ca.

Remarks. Lines (or bands) are to be seen at 3286/81/70/66/55/46, which are shaded, some toward red, some toward violet. There is no evident relation to the spectrum given in Nos. 242, 252.

251. Iron Spark with Self-Induction.

See description under Chart XX, after No. 188.

242 and 252. Phosphorus Line Spectrum.

Material: White phosphorus in heated vacuum tube, capacity in circuit.

Remarks. The spectrum of phosphorus has not been investigated in detail since the work of Plücker and Hittorf. No measurements of the ultra-violet have been made. In the following list the last figure is uncertain to ± 2 A. Examples of stronger phosphorus lines are 2540/59, 3234/37/48 (lens), 3313/74/82, 3423/29, 3507/11/79/96, 3656/80, *3709/21*, 3806/31/87/89, 3982, 4022/47/63/84/94/97, 4113/20/31, *4182*, *4226*, 4248/*50*, 4389, 4417/21/24/56/66/70/72/79, 4503/36/59/62/69, *4592* (lens), *4606*, 4631/62/72, 4940/48/57/64, 5258, 5301, 5321/49/91, 5414/*31*, 5455/66, 5504, *6029/49*, 6444, 6473, 6623 (2$^{\text{nd}}$ order?).

243 and 253. Oxygen Line Spectrum.

Material: Oxygen at 2 cm pressure in vacuum tube, capacity and spark gap in circuit.

Impurities: C (2479, 2509/12, 2837, 3922, 4267).

Correction: (253) —4.

Remarks. This is the so-called elementary line spectrum. Variations of pressure and other conditions cause oxygen to show three other spectra, viz. a continuous spectrum, a band spectrum and a series spectrum. Stronger lines of the elementary spectrum are seen at 3135, 3390 (lens), 3713/27/50, 3866/77/82, 3912, *3919* (lens), 3945/48/55/*73*/83, *4070/72/76*/79/85/89/93/97 (?), 4105/11/12 (lens)/21/22/33/44/53/57 (lens)/69/86/90, 4254 (dif)/76 (?), 4304/17/20, group between 432 and 435, 4367/69/96, *4415*/17/43, 4448/53/66/68/70 (lens), 4591/96, 4610/39/42/51/62/76, 4700/06/10, 4907/25/41, 4943/55, 5176, *5208*. In addition, diffuse maxima appear at 5335, 5440, 6110, 6170, which have the appearance of broadened lines and perhaps come from the lines 5330, 5437, 6172 of the compound and line spectrum.

244 and 254. Sulphur Line Spectrum.

Material: sulphur in heated quartz tube, capacity in circuit.

Remarks. Sulphur shows two line spectra. One has a regular structure and is called the compound or series spectrum. The other, richer is called lines in the "elementary" spectrum, and is the one here reproduced. No lines appear below 3000 in this spectrum. Eder and Valenta (Beiträge, p. 274) used glass apparatus and consequently could not photograph below 3000. We have used a quartz tube, and the more refrangible part is still lacking, with the capillary viewed either from the side or end-on; so we must conclude either that a very thin layer of sulphur vapor is sufficient to absorb all ultra-violet light, or that sulphur has no lines in this region. The first alternative seems improbable. The photographs were taken with high vapor pressure, with the result that the spectrum is rich in lines and most of the lines are broadened. The stronger lines of S are found at 3325/67/70 (d)/87, 3497, 3669, 3784, 3832, 3932/33 (lens), 4020/33, 4142/45/53/63/74, 4295, 4464 (2 comp.), 4525/52, 4716, 4816, 4924/25 (lens), 5010/14/33, 5104, 5201/13, 5321/46, 5429/33/54, 5510, 5606, 5641/47, 5820, and also the lines 5870, 5996, 6103, 6286, 6306/23/98, which have not been previously photographed. All of these lines, with exception of those first in the list, are very strong.

245 and 255. Sulphur Band Spectrum.

Material: sulphur in heated quartz tube; no capacity in circuit.

Remarks. The sulphur bands are seen by the aid of a lens to be composed of numerous fine lines; but the dispersion given by the photograph does not suffice for complete resolution. The edges of the bands are more prominent on this account. Bands are to be seen as far as 626 at one end and 247 at the other. Those above 56 and below 36 are photographed here for the first time.

246 and 256. Selenium Line Spectrum.

Material: selenium in heated quartz tube; capacity in circuit.

Correction: (256) + 2.

Remarks. Selenium shows various spectra under different conditions, a series spectrum, a banded spectrum (photographed by us in the same manner as that of sulphur) and an "elementary" line spectrum. We give only the last named here. It had been previously photographed only in the region of shorter wave-length. Some of the stronger lines are found at 2592, 2631/87, 2720/78, 2817/38, 2915/52/73 (d), 3040/41/90, 3386, 3414/59, 3543, 3637, 3712/39, 3802, 3936, 4004/09/31/72, 4109/27/30/33/37/76/83, 4214/16, 4322/84, 4469, 4566, 4606/50, 4842/47, 4977/94, 5072/93/99, 5143/79, 5230/54/73, 5307, 5525/69/93, 5625, 6059.

247. Tellurium Arc.

Material: Tellurium in carbon arc.

Impurities: Cy, Ca, Cu, Ag, Mg.

Correction: + 1.

Remarks. Tellurium has several spectra of bands and lines of which, on account of the high melting point, only the line spectrum is readily obtained in arc and spark, and we reproduce only this spectrum. Tellurium lines are found at *2383* (d, r), *2386*, 2531 (lens), *2770*.

248. Tellurium Spark.

Material: spark between tellurium electrodes.

Impurities: air spectrum, Cu, Ag.

Correction: + 2.

Remarks. First are seen the arc lines, *2383/86*, 2531 (lens), 2770, and in addition a series of strong spark lines, examples of which are at 2712, *2846/58/69/95* (dif), 2942/67, 3018, *3047*, 3074 (lens), 3175 (lens), 3257, 3352/63, 3407/43/55, 3551/53, 3618/45, 3736/98, 3842, *4007*, 4062, 4221, 4302/77. The tellurium lines are all more or less strongly broadened.

249 and 259. Chlorine Line Spectrum.

Material: Chlorine at about 35 mm pressure in glass vacuum tube.

Impurities: H (with broadened lines at 655, 487, 435).

Remarks. See the following spectrum.

257 and 258. $SnCl_4$ in Vacuum tube.

Material: $SnCl_4$ vapor at 8 mm pressure in vacuum tube with quartz window. No capacity in circuit.

Remarks. The great affinity of Cl for other elements adds much to the difficulty of using the gas in tubes. It is necessary then to use glass tubes and thereby sacrifice the ultra-violet spectrum. Fairly high pressure can be used with the best effect. Nos. 249 and 259 were taken under these conditions. As a result of the pressure the Cl lines are much broadened and a continuous ground appears, the latter phenomenon being usual with Cl. The spectrum extends only to 30 on account of the absorption of the glass. To obtain sharper lines, lower pressure must be used, which gives further trouble with chlorine, as the tube lasts but a short time. We found the Cl spectrum given much more conveniently when the tube was filled with $SnCl_4$ vapor. Nos. 257 and 258 show the Cl lines sharp, and the tube can be used with quartz window. A remarkable phenomenon is that the line spectrum of tin appears strongly at the same time with that of Cl, without the use of capacity and apparently without dissociation of the gas. It is the spectrum of the tin spark. We shall begin with the description of Nos. 257 and 258. Tin lines appear (comp. Nos. 90 and 100) at 6453, 5799, 5595/64, 5368/48/33, 5290, 4859, 4586/25, 3801, 3352/31, 3284/62, 3175, 3033/09, 2863/51/40, 2707 (lens). If we compare this spectrum with that of the tin arc and spark, we see that it strongly resembles the latter. Some prominent arc lines, as 5632 are entirely absent, while all spark lines are strong. — Examples of stronger Cl lines are at 3329, 3750/99, 3805/46/51/61, 4133, 4234/35/41/54, 4307/43/73, 4526/70/73, 4741/69/71/81/95, 4810/20/96, 4905/17/24/70/95, 5078/99, 5103, 5218/21, 5392, *5423/44/57*, 6095. The same lines are visible in (249) and (259), but are broadened throughout and in some cases enhanced. This is true especially of the lines 3307/15(lens)/17/29/34/53.

250 and 260. Bromine Line Spectrum.

Material: bromine in vacuum tube; pressure about 10 mm; capacity in circuit.

Impurities: H (traces at 656, 485).

Remarks. Bromine possesses a band and a line spectrum. We give only the latter. Stronger lines are found at 6351 (lens), 6150, 5831, 5719, 5590/07, 5495/89/23, *5332*/04, 5238, 5183/65, 5055, 4931, 4817, 4786/77/67, *4705*, 4679, 4623, 4543, 4366, 4224, 3981/25/20(d)/14, 3835 (lens). Other lines appear near 2927, whose connection with bromine is uncertain.

Charts XXVII and XXVIII.

261 and 271. Iodine in Vacuum Tube.

Material: iodine in quartz tube, capacity in discharge circuit.

Impurities: H 4861 (broadened).

Remarks. The spectrum here chosen out of the different spectra given by iodine in a vacuum tube is that obtained most easily at moderate vapor density when the lines in the green broaden and the discharge in the wider part of the tube assumes the from of a green thread bordered with red. Examples of stronger iodine lines are those at 2466, 2567/83/94, 2676/90, 2714/32/60/91/92, 2819/21/74/80, 2917/50/58/59, 3039/55, *3078/97/82/83*, 3140/50/95, 3231/75/88, 3301/03/50, 3414/82/98, 3661/83, 3787/88, 3742, 3808/22, *3898*, 3931/38/40, 3984, 4071, 4129/34/36, 4219/21/24/26/36, 4335/39/42/76/99, 4409/53, 4513/28/44, 4600/22, 4667/76/77, 4731/66/69, 4851, *5101*, 5338/45/70, *5405*/07, 5464, 5497, 5626/91, 5711/39/75, *5950*, 6074, 6126.

262 and 272. Hydrogen in Vacuum Tube.

Material: hydrogen in glass tube, no capacity in circuit.

Impurities: (262) Cy 3884 (from grease in pump).

Correction: (262) + 2.

Remarks. The elementary line spectrum is reproduced, which appears when hydrogen is not entirely free from oxygen and always when H is present as an impurity. The stronger series lines are 6563 (red, C or H_α), 4861 (blue, F or H_β), 4341 (indigo, G or H_γ), 4102 (violet, h or H_δ). The lines 3970, 3889, 3856, 3798 are indistinctly visible on the reproduction ($n = 3, 4, 5, 6, \ldots 10$). At lower pressure the lines are obtained sharp. Compare the spectra 2, 5, 8, 92, 271, 276, in which the hydrogen series appears at higher pressure and the lines are to be seen in various stages of broadening and reversal. Below 3640 the elementary spectrum of H shows no lines. — Besides this elementary spectrum, H has a second spectrum, very rich in lines.

263 and 273. Helium in Vacuum Tube.

Material: helium in glass tube with quartz window, no capacity in circuit.

Correction: (263) + 1.

Remarks. Lines of the first principal series are seen at *3889* (br., with ghosts), *3188*, 2945 (lens) ($n = 3, 4, 5$); of the first subseries at *5876* (D_3, with ghosts), *4471*, 4026, 3820, 3705 (lens), 3634 (trace) ($n = 3, \ldots 8$); of the second principal series at 5016, 3965, 3614 (lens) ($n = 3, 4, 5$); of the third subseries at 6778, 4922, 4388, 4144 ($n = 3, 4, 5, 6$) and of the fourth subseries at 5048, 4438, 4169 (trace) ($n = 4, 5, 6$). The helium lines below 2900 have but small intensity.

264 and 274. Argon in Vacuum Tube, Red Spectrum.

Material: Argon in glass tube; 2 mm pussure; no capacity in circuit.

Correction: (264) — 1.

Remarks. Argon possesses three different spectra, of which the red and the blue have no lines in common, while the white spectrum contains the lines of both and shows broadenings, displacements and numerous differences in single lines. The first two spectra are given in Nos. 264, 274, 265, 275. The red spectrum may be obtained alone through proper choice of pressure and electrical conditions. In this regard, compare H. KAYSER, Ber. Berl. Akad., 1896, p. 551—564, and J. M. EDER and E. VALENTA, Beiträge, p. 220 etc. Lines of the red spectrum are to be seen, for example, at 3948/49 (lens), 4045, *4159*, 4164, *4192/98*, *4201*, *4259*/72, 4300, 4334/35/45, 4511/22/96, 4629, *4703*, 5188, 5452 (lens), 5496, 5559, 5607, 5883/89 (lens), 5912, *6031*, 6043, 6059.

265 and 275. Argon in Vacuum Tube, Blue Spectrum.

Material: Argon in glass tube; 4 mm pressure; capacity with spark gap in circuit.

Correction: (265) + 2.

Remarks. The blue spectrum of argon is in general easier to obtain pure than the red (compare under 264) and shows its stronger lines at 3302 (lens)/36/45, 3477/92, 3546 (d), 3577/82/83 (lens)/89, 3638, 3729/81, 3851/69, 3926/29/33, 4014, *4072*, *4104*, 4132/83, *4228*/67/78, *4331*/*48*/52/71/76/80, 4400/01 (d, lens), *4426*/*30*/*31* (d, lens), 4482, 4488 (belonging to a group of lines which appear only with strongly condensed spark), 4545/80/90, *4610*/58, 4727/36/65, *4806*/48/80, 5009 (lens), 5017/62, 6114 (lens).

266 and 276. Carbon Arc.

Material: carbon arc in air, 220 volts, 7 amperes.

Impurities: Ca, Na.

Remarks. The arc burning between carbon rods in air shows two different sets of bands, besides lines from metallic impurities. The bands of the first group lie in the blue, violet and ultra-violet, appear only when nitrogen is present in the atmosphere around the arc and are generally ascribed to cyanogen. These bands lie at 3590 (3 heads, lens), *3884* (5 heads), 4216 (6 heads), 4601 (7 heads, see No. 276). The second group appears to belong either to carbon itself or to one of its oxygen compounds. The bands of this group extend into the infra-red. The separate bands are seen at 4382 (trace, compare No. 478), 4737 (5 heads), *5165* (3 heads), 5635 (4 heads) and from 570 toward greater wave-length. The bands are composed of series of fine lines, several of these series starting from each head and proceeding toward shorter wave-length. The interval between successive lines of a series at first increases, then after a certain point decreases until, in the case of the cyanogen bands, the series reaches a definite ending (tail), having the appearance of a weak head whose lines run in the reverse direction. (Compare in No. 278 at 3900/45/85). Above 570 the whole ground is filled with bands which appear made up of numerous series of lines running to and fro in a highly complex manner. The carbon band spectrum appears in most arc spectra as an unavoidable impurity when carbon electrodes or substances containing carbon are used. See also No. 278.

267 and 277. Carbon Spark: Air Spectrum.

Material: Condensed spark between moistened carbon point in air; no self-induction in circuit.

Impurities: Ca, Na.

Remarks. The spark between carbon points gives two different spectra, according as self-induction is connected in series with the spark or not. In the first case we obtain the spectrum described under No. 278. Without self-induction the spectrum is a combination of several spectra, of which those most often visible are the following: (1) line spectrum of carbon, (2) line spectrum of nitrogen, (3) line spectrum of oxygen, (4) cyanogen band spectrum, (5) line spectrum of hydrogen (with moistened electrodes). In addition to these, certain discharge conditions will give the carbon band spectrum, the nitrogen band spectrum (positive and negative), the spectrum of water vapor, of ammonia, the blue argon spectrum as well as lines from metallic impurities in the carbon. The conditions chosen for this photograph give the spectra (1) of carbon, (2) of cyanogen, (3) of hydrogen, (4) of nitrogen, (5) of oxygen as it is usually given with moistened electrodes. Lines of carbon are to be seen for example at *2478*, 3920, *4267* (see No. 277), 5145. (Compare the spectra Nos. 124, 126, 128, 130, 161, 163, 166, 243, in which the carbon lines, especially 4267, appear strongly as impurity lines). The strongest cyanogen band appears at 3884 and hydrogen lines at 486 (br) and 656 (br). For the spectrum of nitrogen and oxygen (from air) compare Nos. 229. 239, 243, 253. Compare also Nos. 278 and 92.

278. Carbon Spark.

Material: spark between carbon points. Self-induction in circuit.

Impurities: Ca, Na.

Correction: (below 410) +4.

Remarks. In place of the line spectrum of carbon the band spectrum appears when self-induction is included in the discharge circuit. This spectrum is similar to that of the carbon arc, except that the intensity of the cyanogen bands is here relatively greater. Compare Nos. 266 and 276.

92 (Chart X). Carbon Spark in Coal Gas.

Material: condensed spark between carbon points in coal gas.

Remarks. The spectrum obtained is made up of the carbon lines 2478, 4267 (lens), the hydrogen lines 4341, 4861, the cyanogen bands 3590 (lens), 3884, 4216 and the carbon bands 4383, 4737. At 4315 appears a trace of the "hydrocarbon band", which shows also in No. 268.

268. Coal Gas Flame.

Material: Coal gas burnt with oxygen.

Remarks. The spectrum consists of three parts: (1) the band spectrum of carbon (so-called Swan's spectrum see No. 276): (2) a group of bands some running toward red, others toward violet, discovered for the most part by Eder and Valenta; (3) the water vapor spectrum. The spectrum whose strongest part is also given by the inner luminous cone of the Bunsen burner is seen in the reproduction at 4315/06 (strong band of second group, from which lines belonging to a weaker band go out), at *3062* and *2811* (lens), the heads of two water vapor bands shaded toward red.

269 and 279. Carbon Monoxide.

Material: CO in vacuum tube; no capacity in circuit.

Impurities: C.

Correction: (279) – 100.

Remarks. The spectrum of carbon monoxide, which easily appears as an impurity in vacuum tube spectra, is composed of numerous bands shaded toward violet and scattered over the whole spectrum. Some of the strongest are at 4123, 4393, *4511*, *4835*, *5198*, 5610, 6079. The carbon band spectrum appears at 4735, 5165, as well as the cyanogen bands at 3590, 3884, 4216 from impurities. In the band 3884 the intensity minimum between the first and second heads is noteworthy as appearing when one works, as here, at reduced pressure. The same phenomenon appears in other bands and in certain stellar spectra.

270 and 280. Solar Spektrum.

Remarks. With the small dispersion here used the photograph shows less than can be seen with the eye, as the fine dark lines do not show in the photograph unless exactly the proper exposure is chosen for each part, which is impossible in the same photograph on account of the varying sensitiveness of the plate. The reproduction in Nos. 270 and 280 gives therefore only a general idea of the spectrum. A number of the stronger FRAUNHOFER lines are visible as follows (the letter designating the line is placed in square brackets, the element in parentheses): 3565 (Fe) 3570 (Fe, d) 3581 (Fe) [N], 3618/32 (Fe), 3720/23 (Fe, Ni), 3728 (Fe) [M], 3735/37 (Fe), 3746/48/50 (Fe, lens), 3816/21 (Fe) [L], *3934* (Ca) [K], 3944 (Al), 3962 (Al), *3969* (Ca) [H], 4005/46/64/72 (Fe), 4103 (Si), 4227 (Ca) [g], 4261/72 (Fe), 4308 (Ca) [G], 4326 (Fe) [f], 4384 (Fe) [d], 4405 (Fe), 4571 (Mg), 4703 (Mg). 4861 (H) [F], 4891 (Fe), 4919/21 (Fe), 4958 (Fe, d), 5042 (Ca), 5065 (Ti), 5140/42/43 (Fe), 5168 (Mg) [b_4], 5169 (Fe) [b_3], 5173 (Mg) [b_2], *5184* (Mg) [b_1], 5230/33 (Fe), 5267 (Fe), 5270 (Fe, d) [E], 5324/33 (Fe), 5529 (Mg), 5616 (Fe), *5890* (Na) [D_2], 5893 (Ni), *5896* (Na) [D_1], 6137 (Fe), 6162 (Ca), 6278 (border, O of air) [*a*], *6563* (H) [C], 6678 (Fe), 6867 (border, O of air) [B].

For the division of the colors see p. 2 of the text.

Spectroscopic Notes*.

Photographic Processes.

As the spectrum given by each of the concave gratings lay on a circle of 50 cm radius, it was necessary to give the photographic plate a large curvature. We succeeded in taking a large number of photographs on thin glass plates with short exposures, but on account of the uncertainty and large percentage of broken plates, we have used plane celluloid films for most of the work. These have indeed their disadvantages, especially as they do not give as clear reproductions and are much harder to handle. For the ultra-violet part we have usually used orthochromatic films [Schleussner or Perutz-Perorto (Grünsiegel)]. For the visible spectrum, it was necessary to sensitize our own films; and we are indebted to Dr. E. König** for coloring matter and methods, as he supplied us most kindly with chemicals and receipts. We used for the most part orthochrome T, and also pinachrome*** and sensitized fresh films supplied by the Aktiengesellschaft für Anilinfabrikation in Berlin.

As developer the commercial preparations of ortol, hydrochinon, edinol, glyzin and others were used. Glyzin developer gave the best results for the films sensitive to red.

The photographs were never intensified, nor altered in any way after being dried.

The time of exposure varied from one second to several hours according to the part of the spectrum, source of light and other circumstances. Several exposures were almost always made, usually with different times, and afterward the best photograph chosen.

In order to obtain as uniform an action as possible over the whole spectrum, numerous ray filters were employed. For the ultra-violet several millimeters of a very thin solution of demethylnitrosoanilin in glycerine according to the method of Wood proved useful in restraining the blue as compared to the ultra-violet in some cases.

In the region of greater wave-length, where the second order spectrum must be excluded, we used as a rule a thin water solution of potassium bichromate 1 cm thick as filter, the concentration of which was adjusted by the spectroscope. We also made use of a number of colored glasses and of Miethe's gelatine foil, in order to allow a longer working of the part of the spectrum lying toward the red and in this way equalize the falling off in sensitiveness of the film.

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* In the following pages only such notes are given as have direct application to the Atlas. For all details and descriptions of methods reference must be made to KAYSER'S Handbuch der Spectroscopie.

** Dye-factory in Höchst.

*** Also used by EDER and VALENTA, see Beiträge, part. III, p. 166.

Arc Spectra.

It was found most convenient to use a simple hand-regulated arc lamp, not inclosed, in which carbon or metal rods could be clamped. The purest spectra were of course obtained with metal rods. We used in this way rods of aluminium, lead, cadmium, iron, copper, magnesium, thallium, zinc and tin without difficulty for the short times required. (See Nos. 81, 101, 61, 187, 221, 28, 86, 49, 89). In all these cases very pure and strong spectra were obtained. Only in the extreme ultra-violet is the intensity different from that obtained when a salt of the metal is used in the carbon arc, and the intensity in this part seems to decrease with the melting point of the metal. In addition, bright bands appear in the outer region and in the flame-like ends of the arc, similar to these in the oxyhydrogen flame and supposed to belong to the oxide (see, for example, No. 91). If metallic electrodes are used, it is better to employ a high voltage and low current for the arc (see below).

When we had no rods of the metal, carbons without cores were used, the substance was placed in a cavity hollowed out in the lower carbon, and the supply renewed as often as necessary. Direct current was always used and the lower electrode was usually made the positive, though this was not necessary with all elements. On the other hand, some elements give good spectra only when the metal or salt is in the crater of the positive carbon.

The presence of the cyanogen bands is unavoidable with most spectra when the substance is used with carbon electrodes. Some elements burn so vigorously, however, that the cyanogen bands are almost if not wholly suppressed. This is true with the alkali metals, also with Ba, Sr, Mg and with most of the more easily vaporized metals when a large piece of the metal is placed in the arc (e. g. Ag, Hg) so that the arc strikes the metal. With elements not easily melted or when only a small quantity of the substance is to be had, it may require some time for the arc to take hold of the molten substance and vaporize it, as is the case with iridium. The moment is easily recognized by the hissing of the arc when it strikes to the metal, as well as the altered color. The central part of the arc is usually violet, the outer greenish. The spectrum of the inside shows the cyanogen bands (compare No. 266), the outside the so-called carbon bands and often the bands of boric acid. As soon as a foreign substance begins to burn in the arc, these colors change, and many substances may be recognized to some degree of certainty from the color given to the arc.

For most purposes it is advantageous to project a magnified image of the luminous source by means of a lens on the slit of the spectrum apparatus. A brighter illumination of the slit is thus obtained, the whole aperture of the apparatus can be used, different portions of the luminous source can be examined and lastly the light from the glowing electrodes can be excluded which otherwise gives a continuous spectrum superposed on that to be observed. We have used different quartz and glass lenses, as well as a condenser made after SCHUMANN'S plan from two cylindrical quartz lenses.

A high voltage arc current has the advantage of giving a longer arc with less heating of the electrodes. In our work, we have employed direct currents either of 10—20 amperes with 72 volts or 5—10 amperes with 220 volts. For most purposes the higher voltage is to be recommended, as then the arc burns very uniformly, the greater length is convenient for projection and the substance is less rapidly consumed. For the study of weak lines, of reversal and broadening of lines, the low voltage and high current are better. The high voltage arc above 10 amperes burns unevenly and is easily extinguished.

The arc spectra are in general distinguished by their intensity in the red and blue, as compared to the ultra-violet. The regularities in structure (series) are most distinct in the arc. The arc spectrum is usually very similar to that given by the spark with selfinduction in the discharge circuit, but essentially different from the regular spark spectrum. The lines given by the flame are generally strong in the are, the weaker arc lines being absent in the flame. The differences in the several spectra arc pointed out in the descriptions. Finally, the arc spectrum remains practically unchanged within wide limits which, combined with its adaptability to almost all substances, gives it the advantage in studies on the connection between various substances and in the establishment of normal spectra. Under great variation of conditions, as with very low current and voltage, high pressure or different atmospheres, the arc spectrum also undergoes change. Spark lines may then appear as well as numerous differences in relative intensity of arc lines. Further, spectra of the metalloids have in most cases not been obtained in the arc, exceptions being the spectra of H, N, C, B and P (comp. No. 241) which are sometimes given by unusual conditions: so that for metalloids in general the spark or vacuum tube discharge must be used. Concerning the band spectra given by almost all elements in the arc, but little is definitely known.

In all arc spectra obtained with carbon electrodes, the constituents of the electrodes give their several spectra along with that of the substance under examination. No element is a priori excluded from possible appearance. Lines found fairly regularly are those of Li, Na, K, Cu, Mg, Ca, Sr, Ba, Hg, B, Si, Pb, Al and Fe. Much more disturbing are the cyanogen bands, and, through not to the same degree, those of carbon. The carbon bands can be strengthened at the expense of those of cyanogen by an atmosphere of CO_2, or the reverse effect obtained with an atmosphere of N, but in both cases the spectrum under examination will probably suffer change. If metallic rods are used to hold the substance the cyanogen and carbon bands do not appear, but we have then the foreign spectrum given by the electrodes. Many elements exert a mutual disturbing influence when burnt in the same arc.

In consequence of the fact that the arc spectrum as a rule contains the strongest lines of the elements and these which appear at all "temperatures" as long lines, and further since a considerable quantity of the luminous vapor is generated, we find many reversals and broadenings appearing. These are especially frequent in the region of shorter wave-length.

Spark Spectra.

Electrodes. Pieces of metal were used as electrodes whenever possible, being placed vertically, with the distance between varying according to circumstances. Metallic salts were used on carbon electrodes. We used for this purpose small charcoal rods, which were prepared and purified with great care by Dr. BETTENDORFF. Our experience is the same as that of others that carbon rods are not to be obtained absolutely pure, as the calcium lines and some others appeared in spite of all the pains that had been taken. This being the case, we have often used carbons for spark electrodes which we had already used in the arc with the same substance, and obtained good results. As with the arc, an image of the spark was projected on the slit.

Variability of Spark Spectra. The spectrum of the spark is perhaps the most changeable of all spectra. The current source, the capacity, the self-induction in circuit, the manner of interruption of the primary current, the current strength, the frequency of interruptions, the spark length, the temperature of the electrodes, the chemical nature of the surrounding gas, the region of the spark itself, all have their influence on the appearance, the intensity of the spectrum as a whole and the relative intensity of separate lines. In this way each element and almost every line offers a wide field for special investigation, and it would be quite impossible to take account of all possible conditions in the narrow compass of an atlas. We have therefore limited ourselves to those laboratory means which are regarded as the typical equipment for the production of spark spectra and which can be employed almost anywhere. Within these limits we have however introduced as many variations as possible in order to give characteristic examples for each case.

Suppression of Air Lines. On some grounds it would have been desirable to avoid the air spectrum, often very disturbing, by the use of a suitable self-induction in the circuit and produce all spark spectra in the manner which we have as a rule used only for the one half. We have preferred, however, to employ the old method for the majority of the ultra-violet spectra and allow the air lines to remain. For it is in the ultra-violet that the difference between arc and spark spectra is the greatest, and the use of self-induction weakens the characteristic spark lines in this region so much that these differences are made much less striking. When no large differences were to be expected in the visible portion, the air spectrum was suppressed by the use of self-induction, and the region common to both photographs is given with and without the air spectrum. With elements having characteristic spark lines in the visible portion the usual condensed spark was used: for some elements which were frequently employed as comparison sources or electrodes, we have given both kinds of spectra (compare Nos. 251, 233, 237, 278).

Apparatus. The induction coil used gave a spark length of 25 cm and was driven by a direct current of 6—8 amperes, the interrupter being of the common hammer pattern.

Parallel to the spark gap were placed one to six Leyden jars each with a capacity of 0,0027 microfarad. From the poles of the inductor, wires were led as straight as possible to the spark gap. An auxiliary spark gap and self-induction spool could be inserted in one of these wires when desired. The self-induction used was a Tesla secondary in a vessel of oil and had a volue of 0,003 henry with a resistance of 8 ohms.

Ordinary spark. Without self-induction a strong crackling bright spark was usually obtained. The electrodes were acted upon, in some cases rapidly wasted away, and salt particles were turned to dust. The spectrum showed, in addition to the broadened air lines and those of impurities such as the carbon lines, cyanogen bands etc., the spark spectrum in the strict sense, i. e. the greater part of the arc lines, some being absent however and others weakened, while others are strengthened ("enhanced lines"). In addition some new lines, frequently very strong, appear ("spark lines"). These appear in the arc only under quite unusual conditions, such as the arc under water, interrupted arc, arc with very weak current etc. In the descriptions are found numerous notes concerning lines of this sort (e. g. for Sn, As, Pb, Bi, Mg, Cd, Sn). In the central part of the spark the spectrum is different from that given by the less luminous outer portion. The air spectrum predominates in the middle, where the initial discharge passes. The metallic lines are relatively stronger in the outer part. This property may sometimes be used to restrain the air lines, as in No. 198. Band spectra also may sometimes appear in the spark (e. g. Nos. 51, 278), though as a rule weaker than in the arc.

"Hot spark". The foregoing applies only when the spark has a certain length. If the electrodes are brought nearer together, the crackling noise passes into a hissing. The discharge is less luminous, the line spectrum of air changes into the band spectrum, only a part of the metallic lines remaining. The electrodes become at the same time very hot and the interrupter works unevenly. A violet glow appears on the electrodes which gives the band spectrum of nitrogen. The phenomenon appears very easily when thin metallic electrodes are used, as with Cu, No. 233.

With self induction. The spectrum changes in a complicated manner when a self-induction of gradually increasing amount is inserted in the circuit of the ordinary spark. This inductance spool must be without iron core, therefore not the secondary of another induction coil. The air lines become weaker and finally vanish altogether as the self-induction becomes greater. At the same time the spectrum of the electrodes undergoes important changes. In general it approaches the character of the arc spectrum. The spectrum becomes weaker in the ultra-violet, stronger in the less refrangible portion, while the intensity as a whole decreases. As the self-induction increases, certain lines pass through maxima and minima of intensity, while some spark lines become weak or vanish entirely. Arc lines appear which are absent in the ordinary spark, and many lines alter their relative intensity. As the fundamental rule for this behavior is not definitely known, the variation must be investigated in each spectrum by itself. Notes on the results of researches which have been made along this line are found in the descriptions. Finally, certain band spectra appear. Carbon electrodes give with self-induction a spectrum similar to that of the arc, composed of the cyanogen and carbon bands (No. 278). Boron gives the boracic acid spectrum (No. 79). Further examples are found in Nos. 215, 251, 228, 200, 37, 196, 238, 235, 175 and others. Another effect of self-induction is to increase the sharpness of lines. We have regularly used the self-induction spool above mentioned with a capacity of 5×0,0027 microfarad, under which condition the air lines entirely disappeared. The charts offer comparisons between spark spectra with and without self-induction, for example, in Nos. 215, 251.

Cooling of the Electrodes. If, with self-induction in circuit, a magnified image of the spark be projected on the slit, it is seen that two luminous flames proceed from each electrode, which give the spectrum obtained. It is therefore important for the brightness of the image that the spark gap be made as short as possible. If this is done, however, the electrodes become rapidly hot and the interrupter works unevenly. A convenient remedy for this is to blow a current of air through the spark, perhaps by the aid of a water compressor. In this way very well developed spark spectra of the alkalis may be obtained, when this is difficult without such an aid. Compare Chart II.

Different Atmospheres. In cases where the use of self-induction would introduce undesirable changes in the spectrum, the air lines or other disturbing action of the air may be eliminated by the use of a different atmosphere. This may be done to advantage, for example, with the alkali metals when it is desired to use the metals themselves as electrodes, which is necessary in order to obtain the complete spectrum. An atmosphere of hydrogen or, for other metals, of coalgas may be used. We made use of the apparatus designed by Eder and Valenta (glass vessel with quartz window and several branch tubes), which we found also very convenient for the examination of poisonous and highly volatile substances (e. g. Arsenic, No. 214). The spectra Nos. 2, 6, 8 were produced in this way. We have then, to be sure, the strongly broadened hydrogen lines (compare 2, 6) or in other cases the coalgas spectrum (92) as impurity. A considerably longer exposure is also necessary. Coalgas cannot be used to advantage for the investigation of the alkalis, as they combine with one of the constituents of the gas. If hydrogen is used, it must be carefully dried, and then works best when allowed to stream slowly through the vessel.

Spark without Capacity. Unless capacity is used with the spark, one obtains besides the air spectrum only very weak metallic spectra in the immediate neighborhood of the electrodes. Metalloids contained in salts do not usually show their spectra in the spark. This may happen under certain circumstances, however, as when a salt in the molten state is used for electrodes.

The impurities appearing in spark spectra are very numerous. In addition to all impurities given by the arc (compare p. 56) we have now the spectra given by the constituents of the air and by combinations of these with each other and with carbon. Thus we may obtain according to circumstances the spectra of H_2O, H, C (lines and bands), N (lines, positive and negative pole bands), O, NH_3, Cy. Compare as examples Nos. 92, 267, 277, 278, 229, 223, 233.

Flame Spectra.

Numerous methods are in use for the production of flame spectra, which fall, however, into two categories. The substance to be examined is either brought into the outer part of the flame by the method of **Bunsen** or a modification of this (pearl of salt, wick, gauze etc.), or the finely pulverized metal or salt is mixed with the gas or air which feeds the flame and so introduced. We have adopted a different procedure, in that we employed a coalgas-oxygen burner throughout, into the flame of which the substance was either dropped as a powder or introduced by means of a small carbon rod. In both cases the substance is brought into the part of the flame immediately in front of the opening of the burner, where the blue cone appears. This may be done very easily, since the coalgas-oxygen flame can be placed horizontally which gives a greater intensity if the observations are made in the direction of the flame's axis. The powder was dropped into the flame from a piece of sheet metal and fell into a pan below. In this way we obtained the spectra of metallic copper, lead peroxide and other substances (see Nos. 268, 119, 120). If a salt is used, a thick paste may be made by adding water and this is brought into the part of the flame mentioned by means of a thin carbon rod. Salts which do not sputter are most favorable, as carbonates, formiates and many chlorides. In some cases ammonium oxalate may be mixed in. The salts usually burn quietly and give very intense spectra, so that we can recommend the method.

The spectra obtained are richer in lines than those from the Bunsen burner; but the difference is really not so great as it at first seems, as the inner cone of the Bunsen flame has been shown by photographic means to give a many-lined spectrum reaching into the ultra-violet. The lines in the Bunsen flame visible to the eye are noted in the descriptions.

As impurities in the coalgas-oxygen flame used appear only the water vapor bands at 2811, 3062, the hydrocarbon band at 4215, and traces of the Swan spectrum (comp. 268), besides lines in some cases from Na, K etc. in the air.

The preponderance of the band spectrum is very characteristic for the flame spectra of most elements, seeming in some cases to come from the oxide, but often from the element itself (e. g. Pb, Cu, B, Ca, Ba, Sr and others). We have found in fact, no metal which does not show traces of bands, at least in the form of a continuous spectrum.

The lines given by the flame are usually not numerous and belong to the strongest (longest*) arc lines. They are often broadened and reversed (e. g. Pb); in the magnetic field some elements belonging to a group have lines which show the same behavior, as the lines Ba 5536, Ra 4826, Sr 4608, Ca 4227. As these show with especial readiness in the flame, they are often spoken of as "flame lines". Compare Nos. 42, 52, 43, 55, 48, 58, 109, 120.

Vacuum Tubes.

In General. Most of the spectrum tubes to be purchased give very impure spectra and are made of glass, so are not suitable for research work and it is necessary in most cases to prepare one's own tubes. With few exceptions, we have used tubes which we ourselves prepared. The form of the tube varied according to the element and the spectral region. For the ultra-violet, tubes fitted with a ground stopper of quartz according to SCHUMANN's plan were used, and part of the time also a tube (from HERÄUS) composed entirely of quartz glass, which proved especially well adopted to the study of Hg, P, S and Se. As however electrodes cannot be sealed into the quartz it is necessary to cement glass into the quartz with the electrodes sealed into the former. Even when the cemented portions could be glass kept tight by suitable water cooling and impurities in the tube avoided, this detracted much from the value of the quartz-glass tube, otherwise so excellent for the ultra-violet.

Air Pump. The tubes were pumped out with a TÖPLER-HAGEN mercury pump, and after being purified and filled, were either sealed off or left connected to the pump through a barometer cut-off. The latter allowed the tube some freedom of motion, so that it could be adjusted in front of the slit.

The details of preparation of tubes were very different for different cases. It is well known that for many elements it is very difficult to prepare the gas sufficiently pure, and also that tubes which at first give quite pure spectra are liable to show contamination when, as was often necessary, the discharge is allowed to pass through for several hours. Numerous experimental devices were employed, of which a short list follows, while the general methods are to be found in KAYSER's Handbuch der Spectroscopie, Vol. I. Compare also the description of the spectrum considered in each case.

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*) If the image of a vertical carbon arc be projected on the horizontal slit of a spectroscope, the spectral lines appear of different lengths. Those emitted both by the middle and by the outer layer of the arc are longest, while those emitted only by the central portion are shortest.

Electrodes. For H, A, N, He, CO large aluminium electrodes were found most suitable. For O, platinum electrodes are better, in spite of the disintegration, as aluminium always gives off CO. For I, Cl, Br, $SnCl_4$, P, S, Se the best results are obtained with platinum electrodes. These are attacked strongly by Cl, Br, P and Se, so that the tubes are soon spoiled. Mercury dissolves Al electrodes, so that the strongest Al lines are obtained along with those of Hg.

Tube Material. Tubes of glass can be used regularly for H, A, O, N, He, CO, I and $SnCl_4$ and in the visible portion for S and Hg. If for an ultra-violet window a ground quartz stopper is used, made tight by a little grease on the edges, pure spectra can be obtained for these substances. The tube must not be heated. Chlorine attacks all material that can be used on the joint and so can be handled only in glass tubes, as is also the case with bromine. We have, however, found another way to overcome this difficulty. See the descriptions of Nos. 257 and 248. Sulphur when heated forms a precipitate on the cooler portions and makes them opaque; so that one must either leave out the ultra-violet or use a quartz tube. Little is gained by the latter, however, as sulphur probably emits no ultra-violet light (compare 244).

Selenium, when used in the elementary state, must be highly heated and then continually gives off gas under the influence of the discharge. It is thus better to leave the tube connected to the pump and to use a quartz tube if possible. Phosphorus changes under the influence of its own ultra-violet light into the red modification. It must then be heated to the point when glass softens. Here also it is better to leave the tube on the pump and use quartz as material.

Form of Tube. It is better to have the tube so that it may be viewed both end-on and from the side. Chlorine and bromine rapidly disappear through chemical action with the electrodes; $SnCl_4$ gradually dissociates; oxygen remains pure only when present in large quantity. With all of these substances, it is well to have a reserve vessel of the gas either connected directly with the tube or through a stop-cock. Hg, P, S and Se give the brightest spectra when they are distilled through the capillary, so that neither this nor the wider part of the tube must be too small.

Stop-Cocks. It is better if stop-cocks and ground glass joints can be avoided entirely. If this is impossible, they may be rendered tight by mercury or a grease which does not vaporize easily. To dispose of grease vapor, a solution of potassium bichromate in concentrated sulphuric acid may be inserted between tube and stop-cock.

Cementing. The two surfaces to be cemented should be fitted carefully together. On the outer edge a little grease is smeared and over this either sealing wax not too hot or a mixture of water glass and asbestos powder.

Purifying Vessels. To absorb mercury vapor, a tube containing gold leaf or sulphur may be connected between tube and pump, and in front of this, to absorb the sulphur vapor, a small bulb filled with copper filings. In ordinary work both of these may be omitted. Water vapor can be extracted with phosphorus pentoxide, iodine by pieces of caustic potash not quite dry.

Filling of Tubes. No fixed rules can be given for this. If a gas is to be used, the tube is pumped out, heated, filled with the gas and used as long as it gives a pure spectrum. In the case of vapor from a liquid, the same procedure is followed, the vapor coming from a flask containing the liquid attached to the vacuum tube. It may then be difficult to extract the vapor from the mercury pump. A prolonged boiling of the liquid followed by cooling may accomplish this. The tube is first filled with saturated vapor at atmospheric pressure and then pumped out till the tension corresponding to the condensation temperature is reached. Solid bodies, such as S, Se, P, I, are placed directly in the tube.

Pressure. The pressure used depends much upon the special purpose in view. In many cases the character of the discharge and so of the spectrum changes with the pressure. In other cases the lines broaden, while in still others a continuous ground appears if the pressure is either very high or very low. The following values give the pressures we have found most favorable to give a strong and relatively pure spectrum of the substance indicated: N or air 3—4 mm, O as high as possible and the same for Cl and Br; H and He about 1 mm, A about 3 mm, CO 1—2 mm, $SnCl_4$ about 4 mm; Hg can be distilled through the capillary; with S, Se or P a certain amount is sublimed in the capillary, which may there be vaporized by heating the tube. Broadening of lines may be reduced in many cases by the use of self-induction: but the whole spectrum may be changed thereby.

Impurities. Any element may appear as impurity in a vacuum tube. Those occurring most frequently are Na, Ca, Al, N (air), A, H, H_2O, CO, C, Cy, Hg. Of these Na, Ca and Al are usually brought out by strong discharges with a narrow capillary, and are no more disturbing than the green mercury line which almost always appears at low pressures. Lines of N, H and H_2O are best eliminated by careful evacuation, heating and long drying. Most troublesome are CO (bands), C (lines) and Cy (3884), which sometimes are not to be eliminated by the greatest precautions, and cause especial difficulty in the preparation of oxygen tubes. The matter is often helped by the use of capacity in the circuit and a spark gap before the tube. Changing the length of the latter alters the intensity of the C and especially of the CO spectrum, and a spark length may by found at which the impurities either entirely vanish or reach a minimum intensity or pass into the less troublesome line spectrum of carbon.

Excitation of Tube. For driving the tubes we have used the apparatus mentioned on p. 57, the essential parts of which were an induction coil, a condenser (Leyden jars) and a spark gap. Concerning the use of these compare the following.

Spectra from Vacuum Tubes. What has been said concerning the variability of spark spectra applies in the same degree to spectra from vacuum tubes. To the conditions depending on the discharge circuit are now to be added pressure, form of tube, impurities, duration of action as determining factors with the alteration of which not merely a simple line but the whole spectrum changes its character. As no fundamental rules are known for these changes and the behavior of spectra have not been sufficiently investigated in detail, the following notes can only serve the purpose of indicating what is in general to be expected and what we have observed under our special experimental conditions.

Without capacity, spark gap or self-induction in circuit, many elements give band spectra, as N (230), P, S (254), Se, Br, I; other elements line spectra, as Cl, O, H, He, $SnCl_4$ (262, 272, 257, 258) and also the first mentioned elements when used in narrow capillaries and under some circumstances at high pressure.

With capacity one usually obtains line spectra, as with P, S, N, Se, Br, I and others. Band spectra may be given however, as with CO or N; and this occurs in the wider part of the tube with the other elements mentioned, so that then they show both spectra at once.

Introduction of self-induction often distroys broadening of lines given at high pressures.

A spark gap in series with the tube sometimes completely alters the spectrum, as with A (274), CO, N.

At high pressure the lines of many spectra broaden, as Hg (66, 67), S (244), H (257), Cl (249, 259). Raising or lowering the pressure changes many band spectra into line spectra.

In mixtures, the spectrum depends on the proportions of the two gases, as well as on pressure, form of tube and kind of discharge.

Spectra of compounds are usually obtained most easily without capacity in circuit. The spectra from the positive and negative poles are often different. Increase of current in primary has often the same effect as increase of capacity (e. g. with I).

Characterization of Spectra.

We will conclude the Spectroscopic Notes with a short presentation of some of the most noteworthy properties of lines and of spectra, as illustrated by the Atlas; while we refer the reader in each case to KAYSER's Handbuch for more extended study.

Number of Lines. The number of lines in a spectrum varies according to the conditions of production, but is at the same time a periodic function of the atomic weight. Examples of few-lined spectra are B, Te, Si, Be, of many-lined spectra Ce, U, Mo.

Kinds of Spectra. The two main classes of spectra, line and band, have been considered throughout the Atlas. The latter class may be divided again into spectra of compounds and band spectra of elements; and a further separation may be based on whether the bands have sharp limits at one side (they are then always made up of lines), or are diffuse toward both sides. The latter sort is found very often in spectra of compounds. Examples of band spectra of elements (sharp on one side) are Pb, Ba, Cu, S, C; of spectra of compounds sharp on one side, CO, Sn, Y, La, Al, diffuse toward both sides Ca, Sr, Ba, Th.

Appearance of Lines. Spectral lines may be *sharp* or *diffuse* (examples, Au and Tl). If the diffuseness is a consequence of pressure (H, Cl, S) or of vapor density (Cu, Ag, Tl), it is called *broadening*. The broadening may be toward one or both sides (examples of both in Cu and Ag). Different lines of the same spectrum may show different degrees of sharpness and unsymmetrical broadening, but lines of the same series are similar in this respect. If a line is emitted at the same time by dense, highly heated vapor and by thinner, cooler vapor, it appears as a bright line with dark middle or is *reversed* (examples, Na, Tl, Ca, Cu, Ag). If several layers of vapor at different temperatures follow each other, the line may show *multiple reversal* as in the case of Sn. Reversals occur most often in the more refrangible part and lines are affected in different ways. In some cases the dark middle is broadened toward one side. „Ghosts" are lines which occur symmetrically placed on both sides of strong lines and which arise from periodic errors of ruling of the grating.

Groups, Pairs, Triplets, Series. Group of lines whose vibration numbers have differences frequently occurring in the spectrum and which show the same behavior under changed physical conditions are considered as belonging together (examples, Bi, Sb, As). The groups occurring most often are of two lines (*pairs*, example Ca) and of three lines (*triplets*, Ca). If such groups are several times repeated and their vibration numbers can be introduced in KAYSER and RUNGE'S formula, such a sequence of lines is called a *series* (examples, Na, K, Rb, Cs, Ca, Sr, Mg, H, He). The same element may show several different series (examples, He, Na, Ca). If the elements are closely related chemically their series show the same structure (compare Rb and Cs), and the behavior of the lines in the magnetic field as well as other criteria allow a classification (*principal series* and *subseries*) (examples, Ca, Sr, Mg, He). The values of the constants in each series, which govern its beginning and course, depend on the place of the element in the system and on the atomic weight.

Spark and Flame Lines. Besides the series lines, most spectra possess a large number of lines which are not to be connected by the KAYSER and RUNGE formula. If these are especially strong in spark spectra, they are called "spark" lines: if characteristic of flame spectra, they are called "flame" lines. Examples of both kinds of lines are to be found for almost every element whose spark or flame spectrum is reproduced in the Atlas (examples, Mg, Pb, Ca).

Multiple Spectra. Almost all elements give multiple spectra, usually a band spectrum and several line spectra (examples, C, N, A, S, O, Sn). The relations of the latter to each other are dependent on the conditions of production. In many cases different spectra appear at the same time, as in the case of carbon.

Spectra of Compounds. Numerous compounds give characteristic spectra which may appear either alone or in connection with other spectra. Spectra of compounds are in all cases band spectra. Examples are given by compounds of Ca, Ba, Sr, Cy, Co, Th, H_2O, B.

Structure of Band Spectra. So far as our present knowledge extends, each band is made up of one or more series of lines which go out from the head and whose number and arrangement vary from element to element and from one compound to another. The arrangement follows a more complicated law than that of the series in line spectra. In the case of cyanogen it is known that the series proceed from the heads of the bands, that the interval between successive lines of a series increase up to a certain point, after which the lines become nearer together until they finally run together in a definite ending, the so-called "tail", having the appearance of a head shaded in the opposite direction from the regular head (compare Cy spectrum). The small intervals between component lines in most bands requires a much higher dispersion than is here offered to enable the details to be seen.

Variability of Spectra. See in this connection the matter on pp. 56, 57, 64.

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The ordinary figures refer to the pages of the text. The figures in **heavy type** indicate the numbers of the spectra in the charts and at the same time the numbers of the descriptions of spectra (pp. 14—53).

Abbreviations: arc = arc spectrum, sp = spark spectrum, fla = flame spectrum, V = vacuum tube, S. I. = self-induction.

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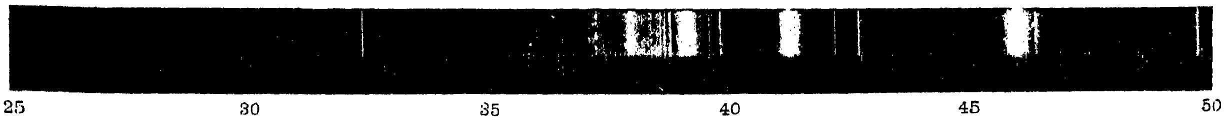
Ant. Kämpfe, Buchdruckerei, Jena.

I. Li. Na. K. Rb.

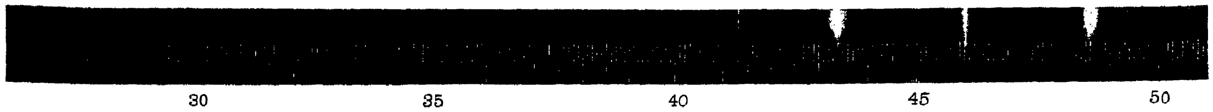
1

Lithium *Lithium*
Arc *Bogen*



2

Spark, *Funke*
Étincelle

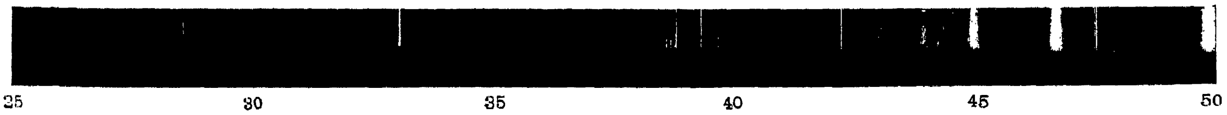


3

Flame *Flamme*

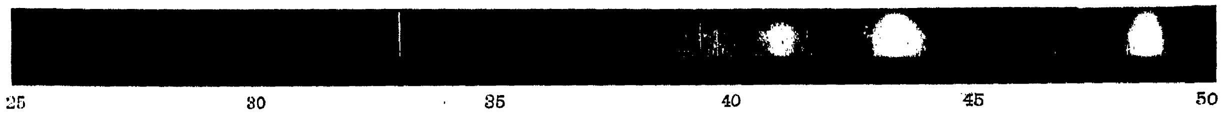
4

Sodium *Natrium*
Arc *Bogen*



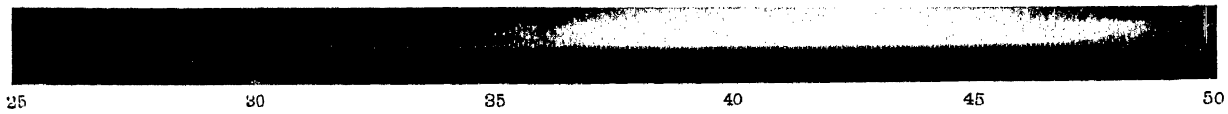
5

Spark *Funke*
Étincelle



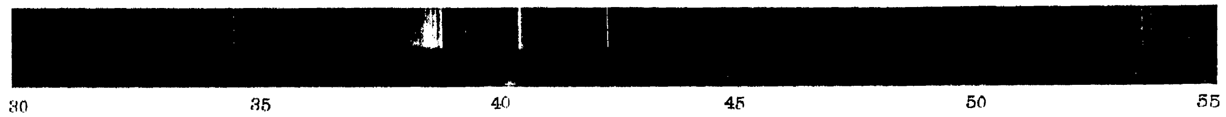
6

Flame *Flamme*



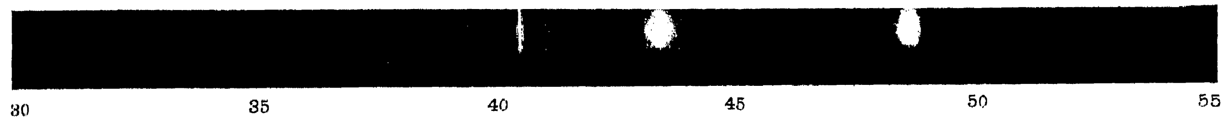
7

otassium *Kalium*
Arc *Bogen*



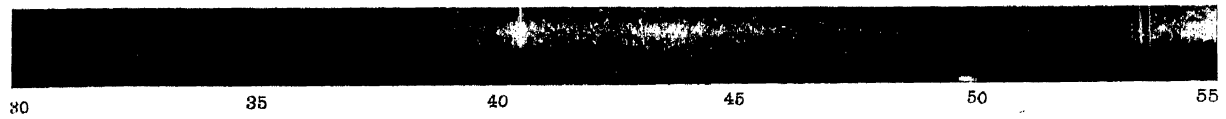
8

Spark *Funke*
Étincelle



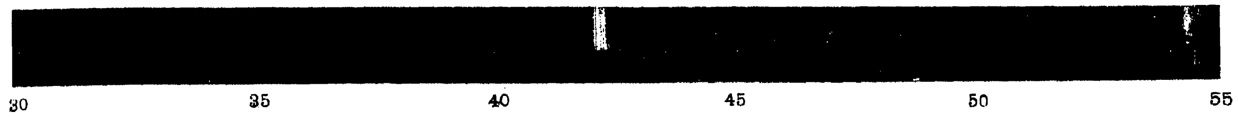
9

Flame *Flamme*



10

ubidium *Rubidium*
Arc *Bogen*

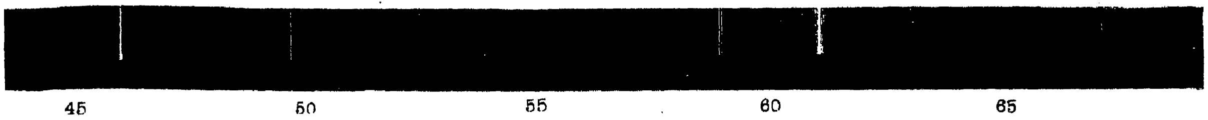


Gustav Fischer, Jena.

II. Li. Na. K. Rb.

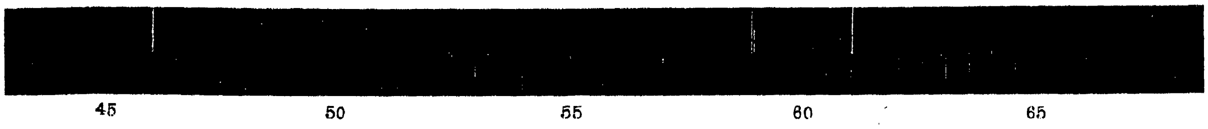
11

Lithium *Lithium*
Arc *Bogen*



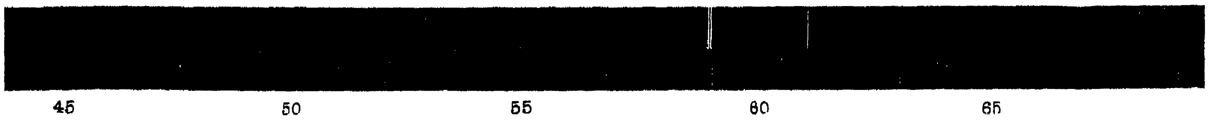
12

Spark *Funke*
Étincelle



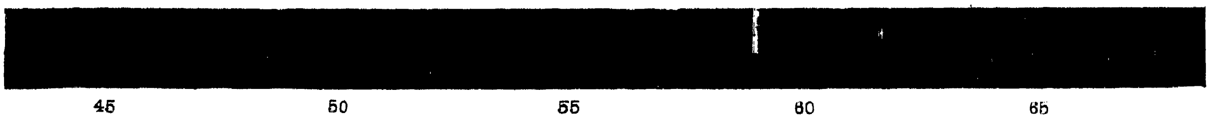
13

Flame *Flamme*



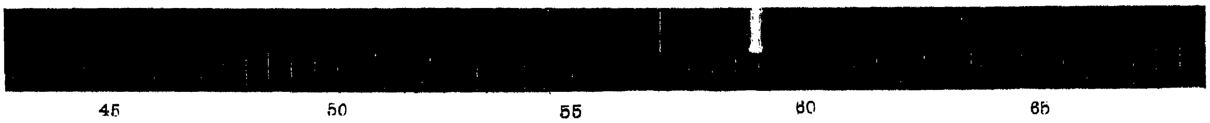
14

Sodium *Natrium*
Arc *Bogen*



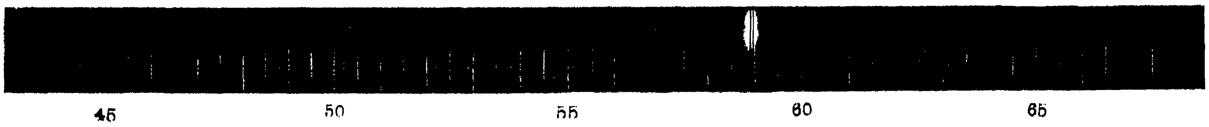
15

Spark *Funke*
Étincelle



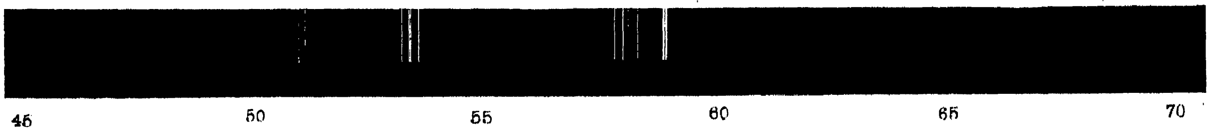
16

Flame *Flamme*



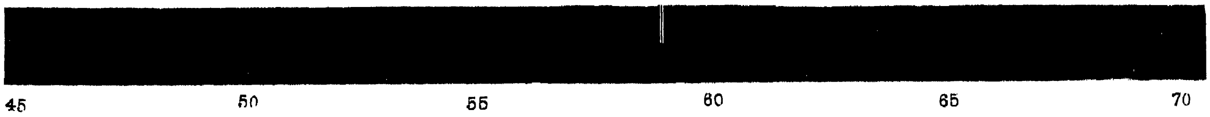
17

Potassium *Kalium*
Arc *Bogen*



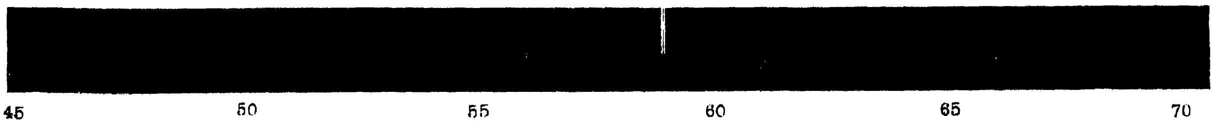
18

Spark *Funke*
Étincelle



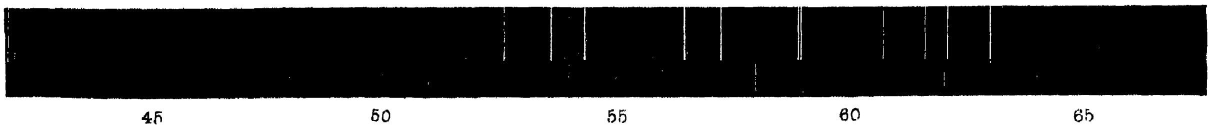
19

Flame *Flamme*



20

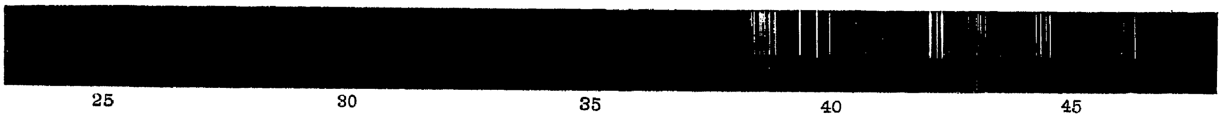
ubidium *Rubidium*
Arc *Bogen*



III. Rb. Cs. Be. Mg. Ca.

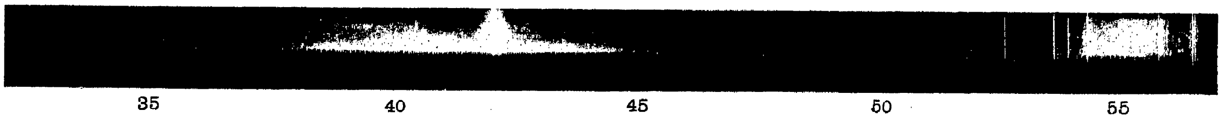
21

ubidium *Rubidium*
Spark *Funke*
ubidium *Étincelle*



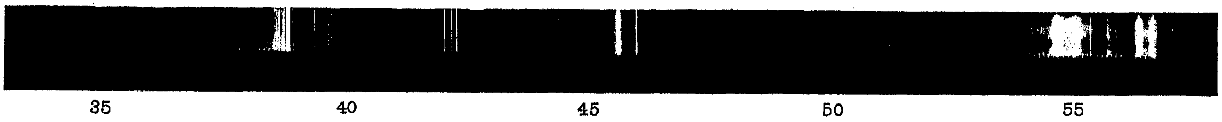
22

Flame *Flamme*



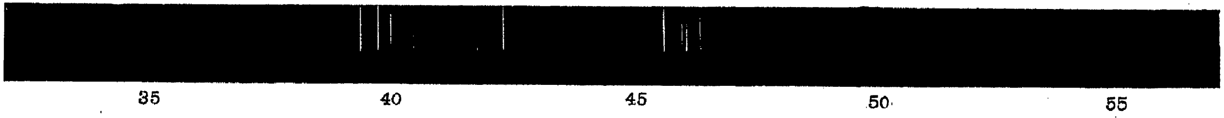
23

Césium *Caesium*
Arc *Bogen*



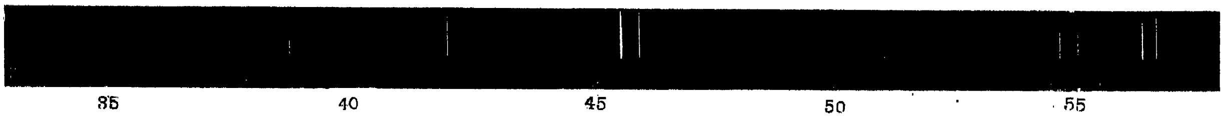
24

Spark *Funke*
Étincelle



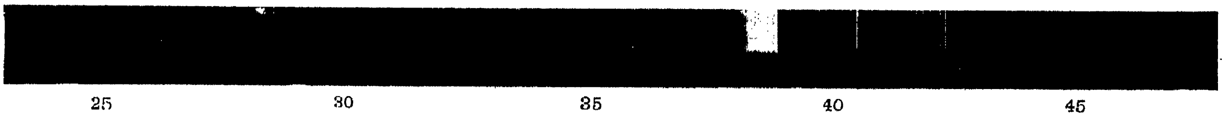
25

Flame *Flamme*



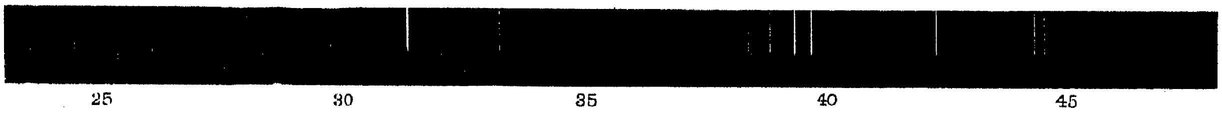
26

Béryllium *Beryllium*
Arc *Bogen*



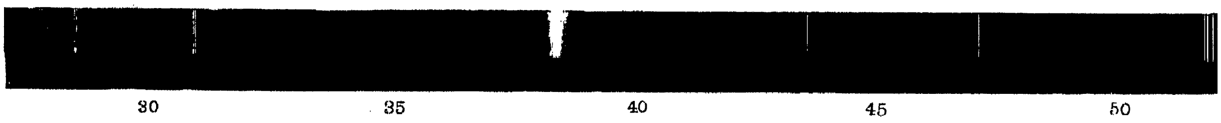
27

Spark *Funke*
Étincelle



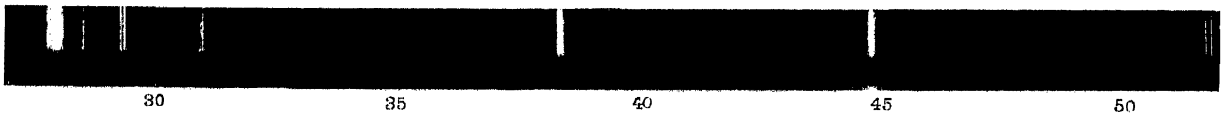
28

Magnésium *Magnesium*
Arc *Bogen*



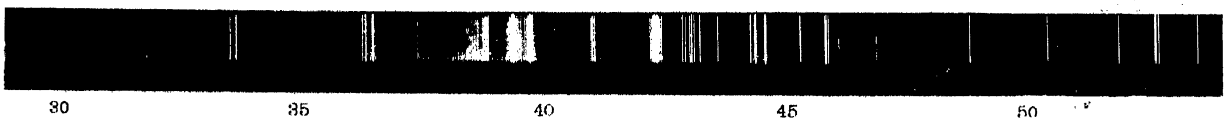
29

Spark *Funke*
Étincelle



30

Calcium *Calcium*
Arc *Bogen*

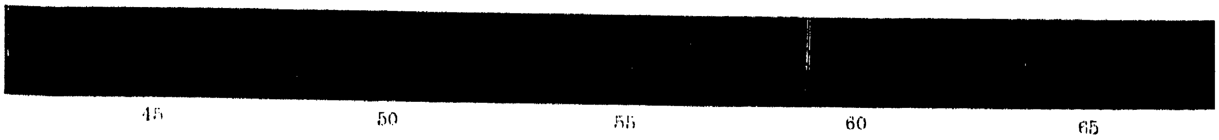


Gustav Fischer, Jena.

IV. Rb. Cs. Co. Mg. Ca.

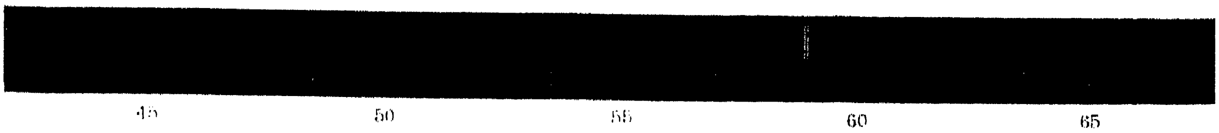
31

Rubidium *Rubidium*
Spark *Funke*
Étincelle



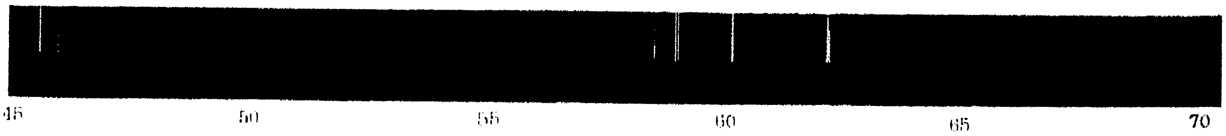
32

Flame *Flamme*



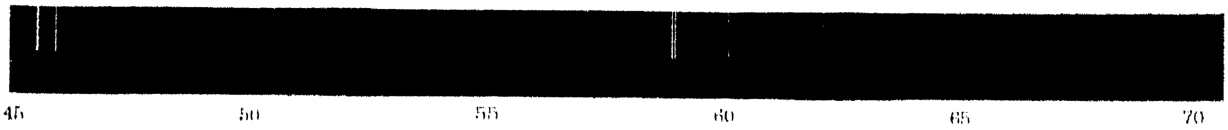
33

Caesium *Caesium*
Arc *Bogen*



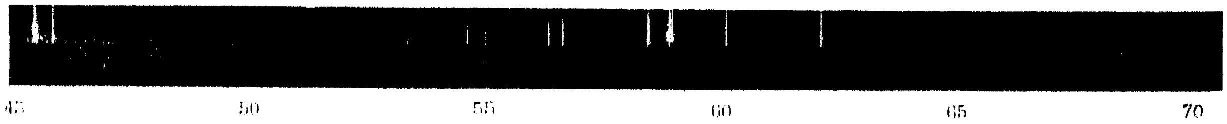
34

Spark *Funke*
Étincelle



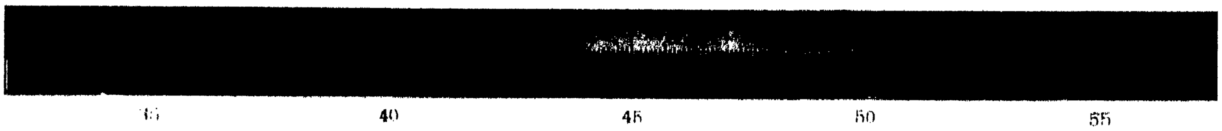
35

Flame *Flamme*



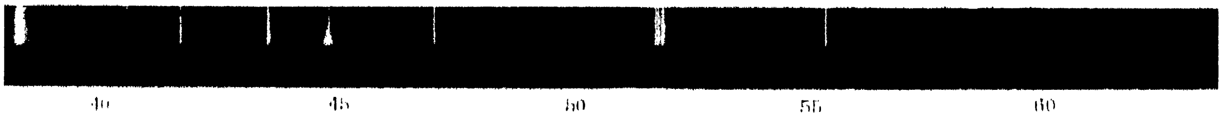
36

Cobalt *Cobalt*
Flame *Flamme*



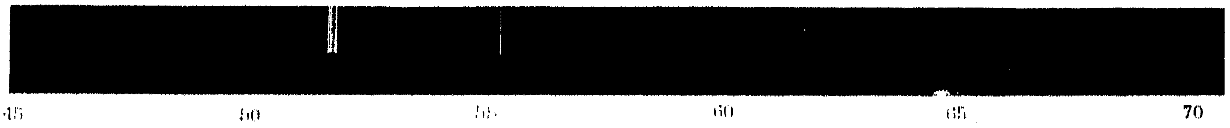
37

agnesium *Magnesium*
Funke [illegible]
Spark [illegible]
Étincelle arc S I



38

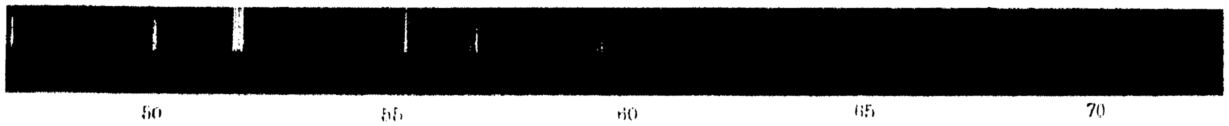
agnésium *Magnesium*
Arc *Bogen*



39

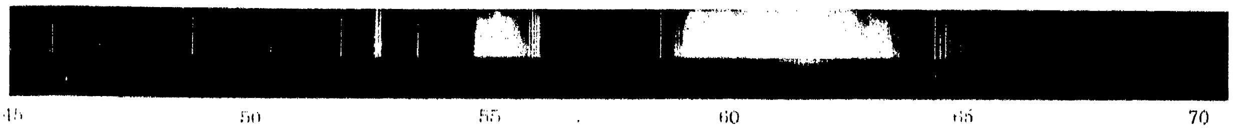
Spark *Funke*

Étincelle



40

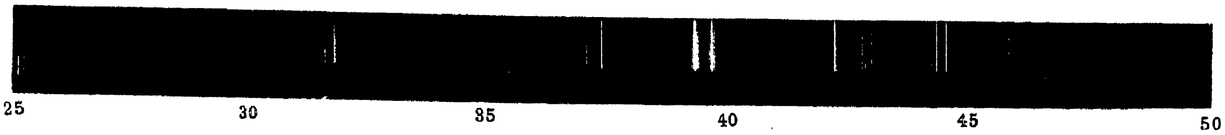
Calcium *Calcium*
Arc *Bogen*



V. Ca, Sr, Ba, Zn.

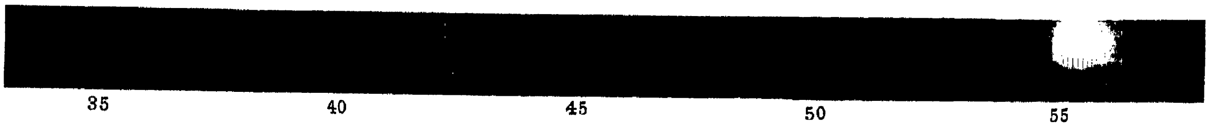
41

Calcium Calcium
Spark Funke
Étincelle



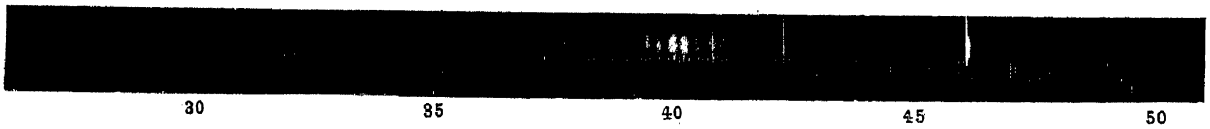
42

Flame Flamme



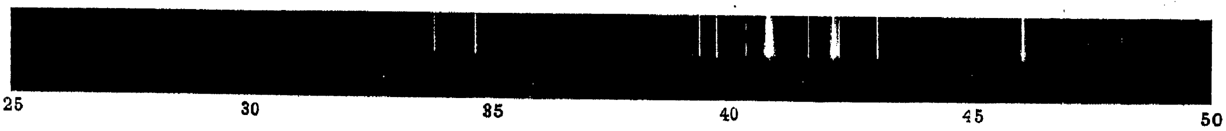
43

Strontium Strontium
Flame Flamme



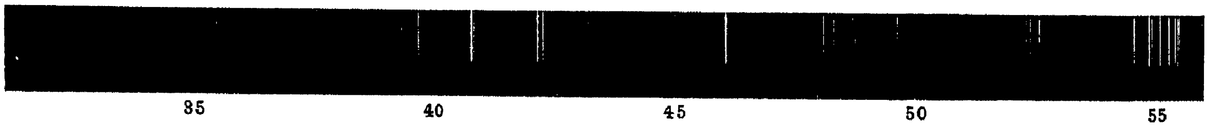
44

Spark Funke
Étincelle



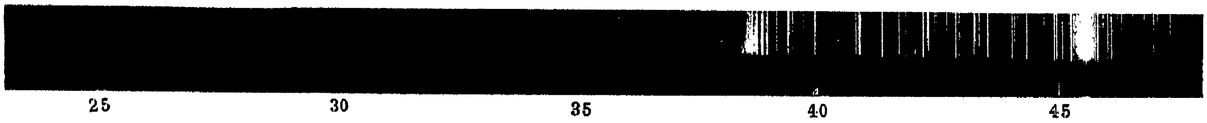
45

Arc Bogen



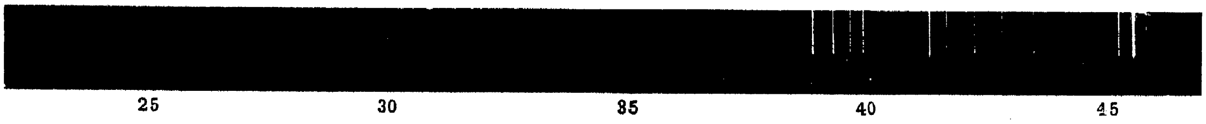
46

Barium Baryum
Arc Bogen



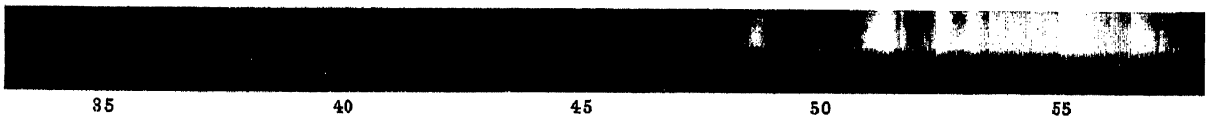
47

Spark Funke
Étincelle



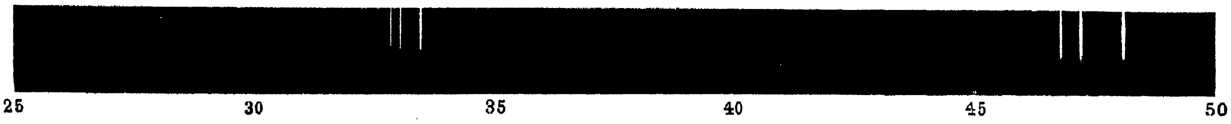
48

Flame Flamme



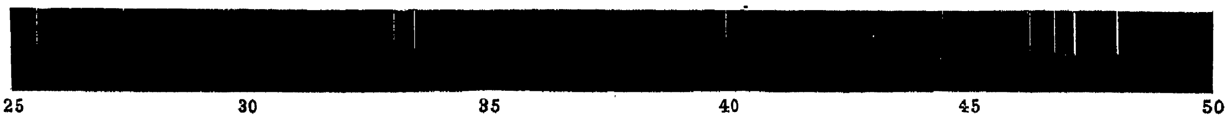
49

Zinc Zink
Arc Bogen



50

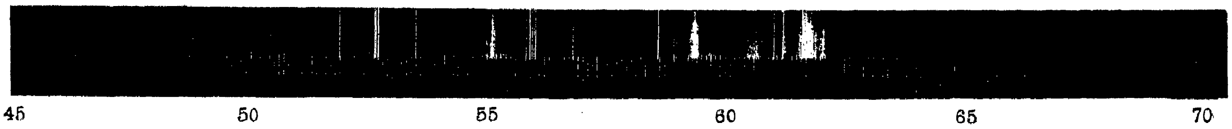
Spark Funke
Étincelle



VI. Ca. Sr. Ba. Zn.

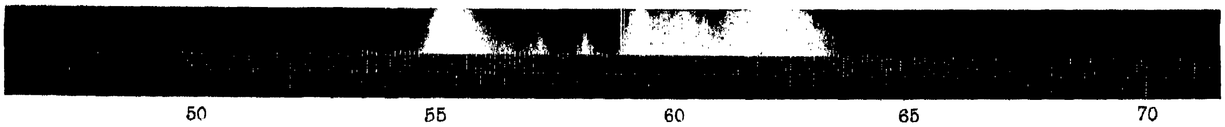
51

Calcium *Calcium*
Spark *Funke*
Étincelle



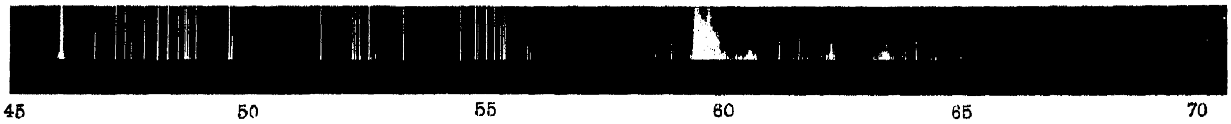
52

Flame *Flamme*



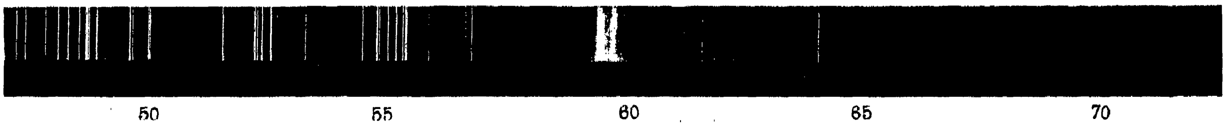
53

Strontium *Strontium*
Arc *Bogen*



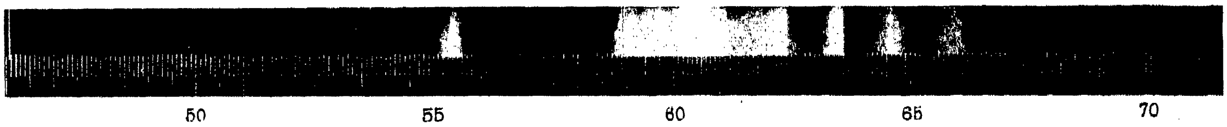
54

Spark *Funke*
Étincelle



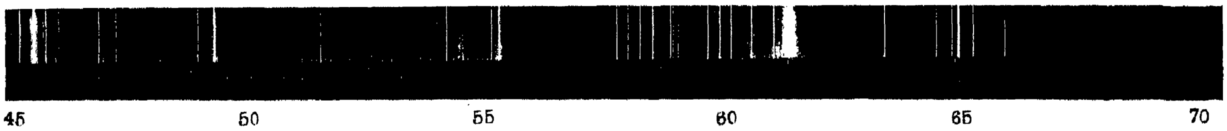
55

Flame *Flamme*



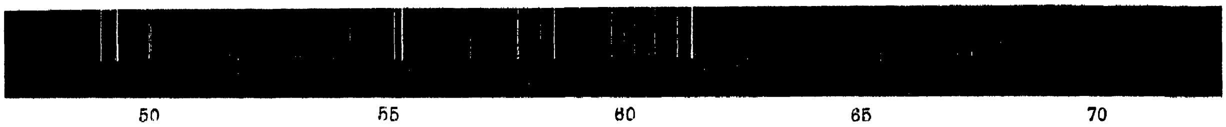
56

Barium *Baryum*
Arc *Bogen*



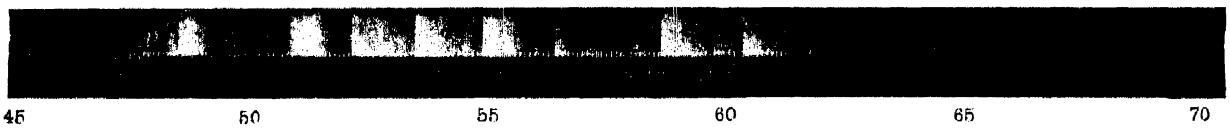
57

Spark *Funke*
Étincelle



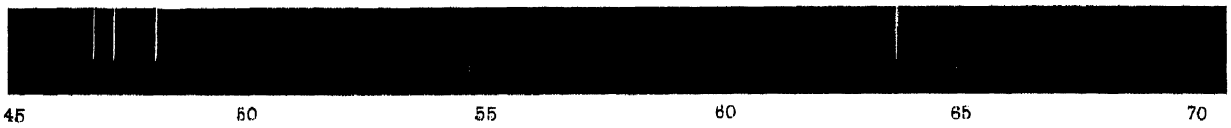
58

Flame *Flamme*



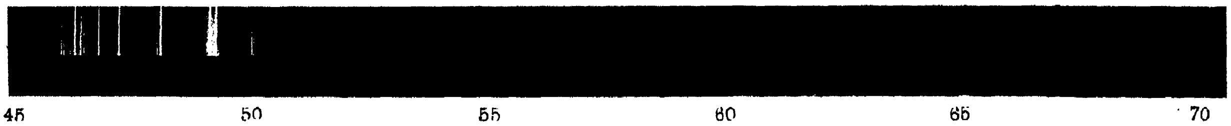
59

Zinc *Zink*
Arc *Bogen*



60

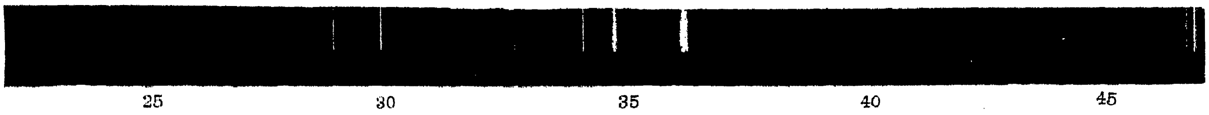
Spark *Funke*
Étincelle



VII. Cd. Hg. B.

61

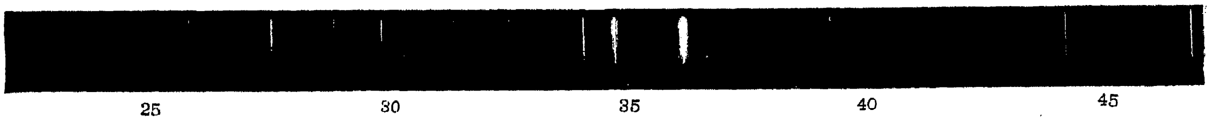
Cadmium Arc. *Cadmium Bogen.*



62

Spark *Funke*

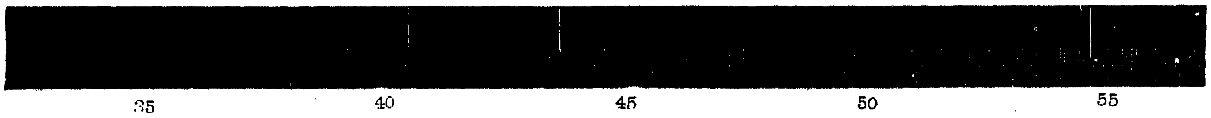
Étincelle.



63

Mercury Vacuum Arc *Quecksilber-Vacuumbogen.*

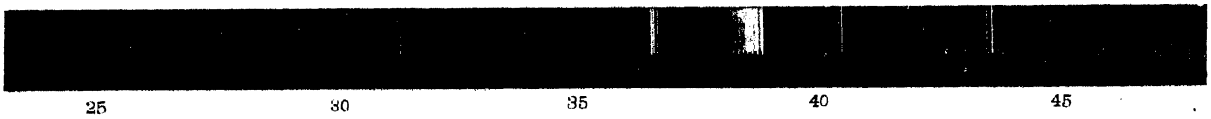
Mercure Arc dans le vide.



64

Arc in Air *Luft-Bogen*

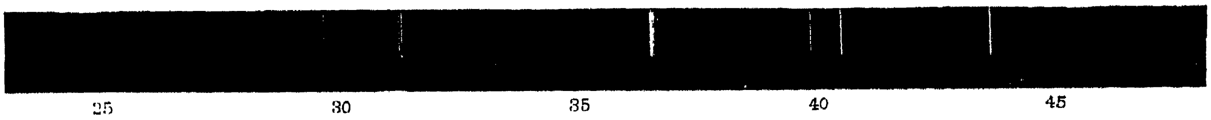
Air Arc.



65

Spark *Funke*

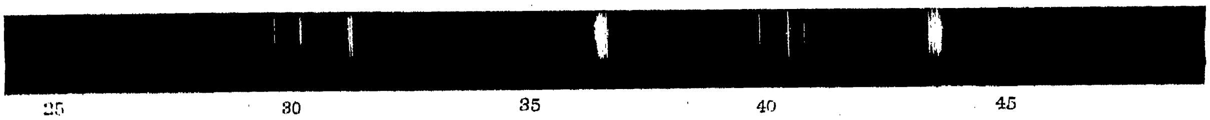
Étincelle



66

uum Tube *Vacuum Röhre*

Tube Geissler



67

d Spectrum *Banden*

Bandes

68

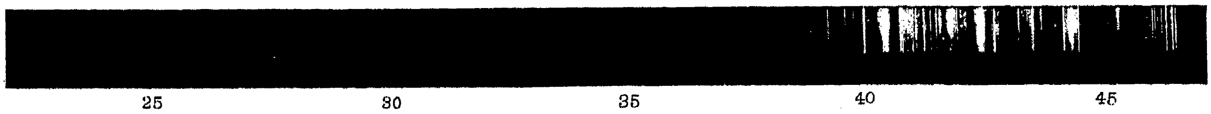
Boron Arc *Bor Bogen*

Bore Arc

69

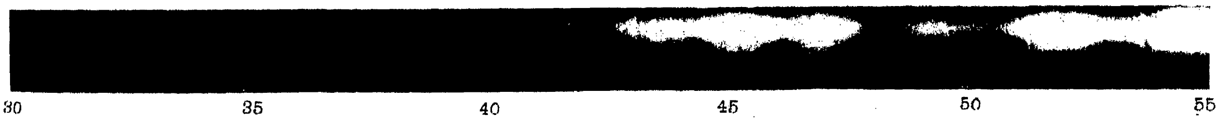
Spark *Funke*

Étincelle



70

Flame *Flamme*

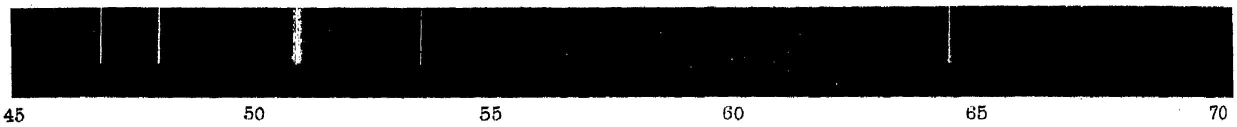


Gustav Fischer, Jena.

VIII. Cd. Hg. Fe. B.

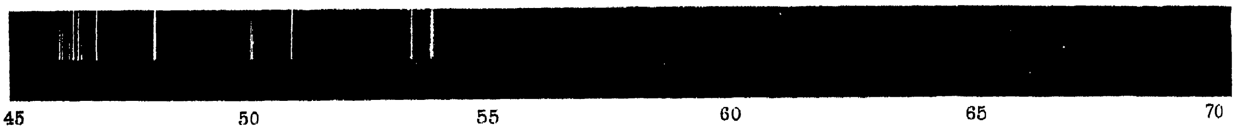
71

admium Arc *Cadmium Bogen*



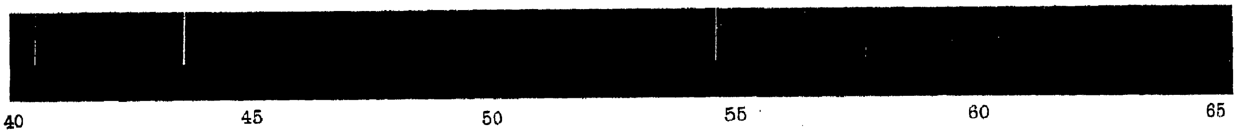
72

Spark *Funke*
Étincelle



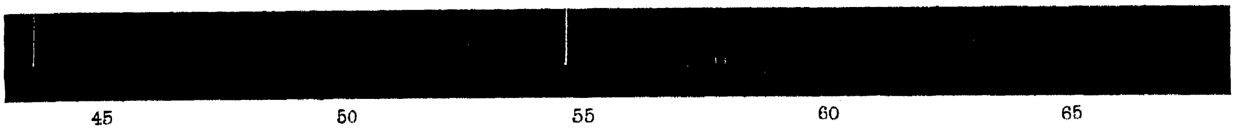
73

Mercury *Quecksilber*
cuum Arc *Vakuumbogen*
ercure Arc dans le vide



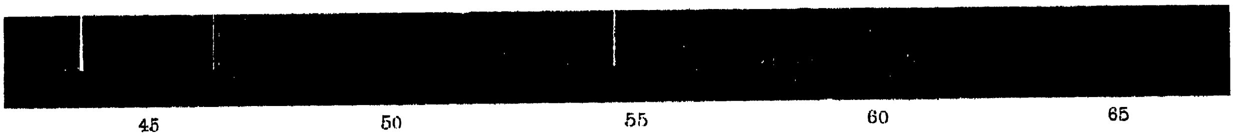
74

rc in Air *Luftbogen*
Air Arc



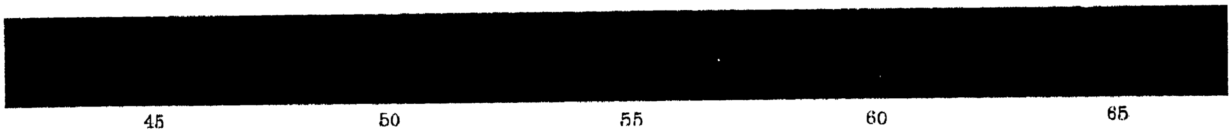
75

Spark *Funke*
Étincelle



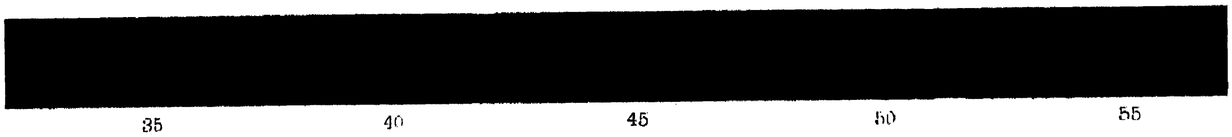
76

cuumtube *Vacuumröhre*
Tube Geissler



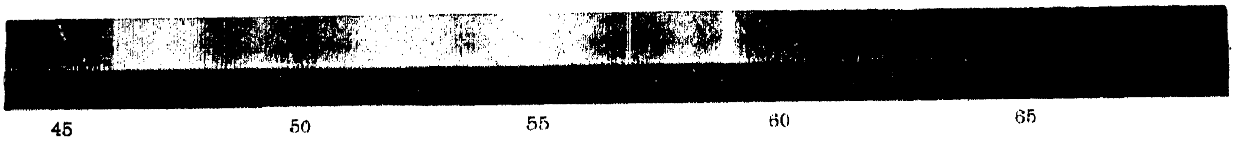
77

ron Flame *Eisen*
Fer *Flamme*



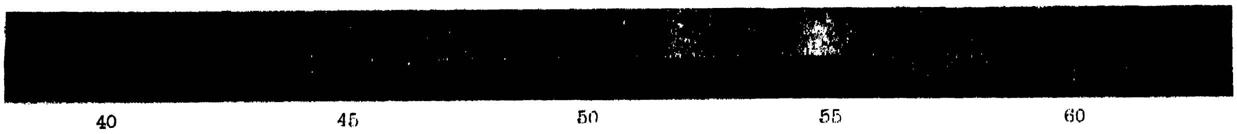
78

Boron *Bor*
Arc *Bogen*
Bore Arc



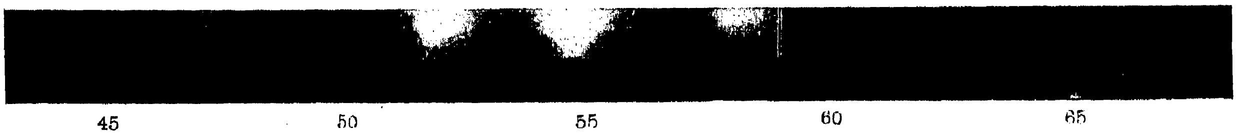
79

Spark *Funke*
Étincelle



80

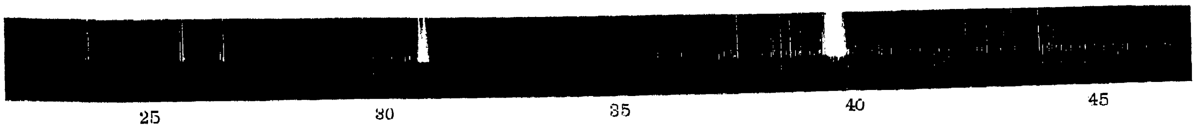
Flame *Flamme*



IX. Al. Jn. Tl Sn.

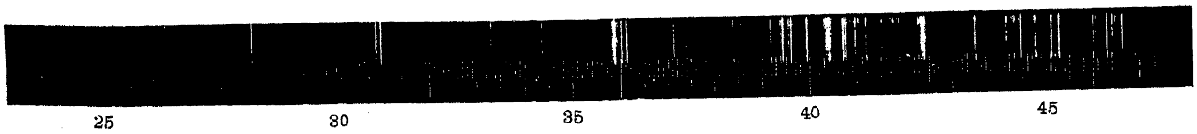
81

Aluminium Arc *Aluminium Bogen*



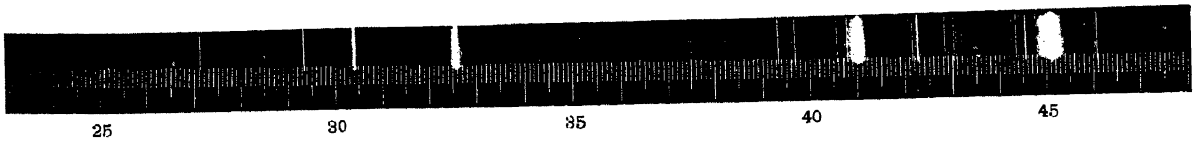
82

Spark *Funke*
Étincelle



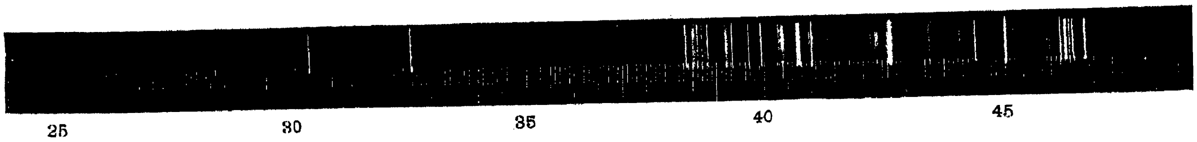
83

Indium Arc *Indium Bogen*



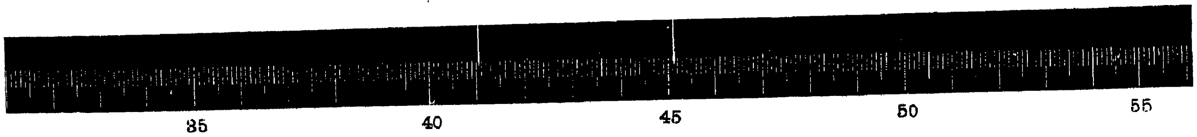
84

Spark *Funke*
Étincelle



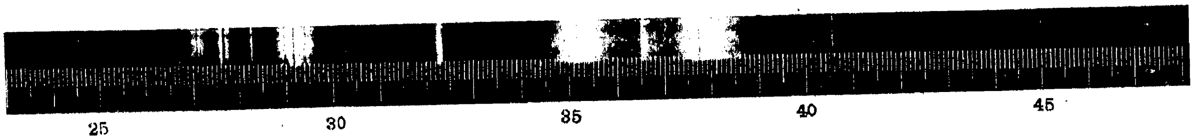
85

Flame *Flamme*



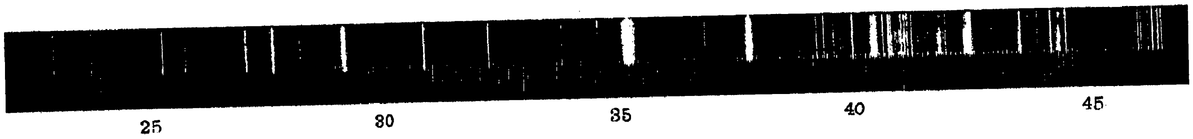
86

Thallium Arc *Thallium Bogen*



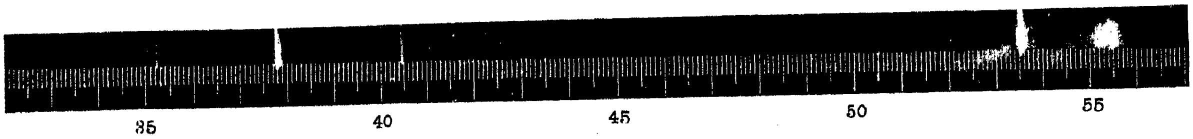
87

Spark *Funke*
Étincelle



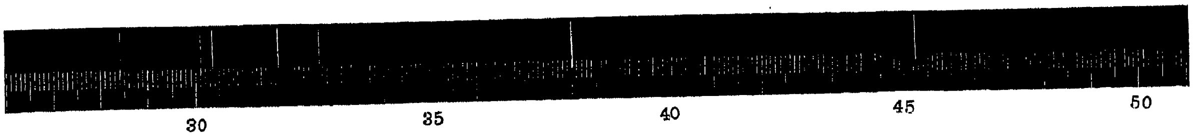
88

Flame *Flamme*



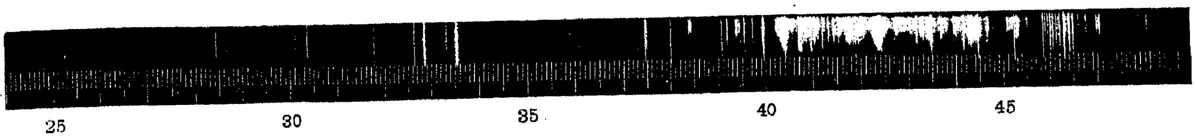
89

Tin Arc *Zinn Bogen*
Étain Arc



90

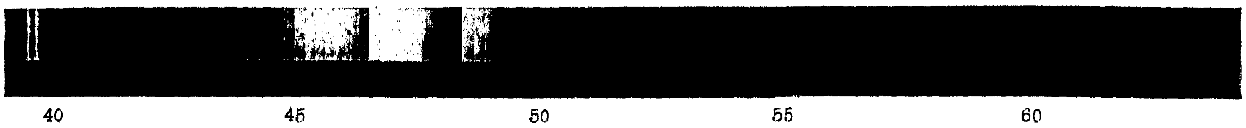
Spark *Funke*
Étincelle



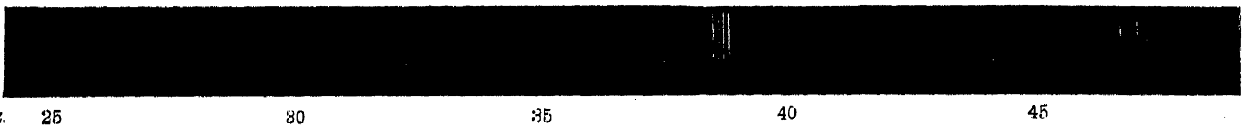
Gustav Fischer, Jena.

X. Al. C. Jn. Tl. Mn. Sn.

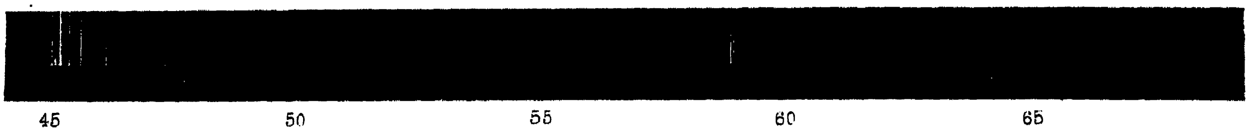
91
minium Aluminium
Arc. Bogen



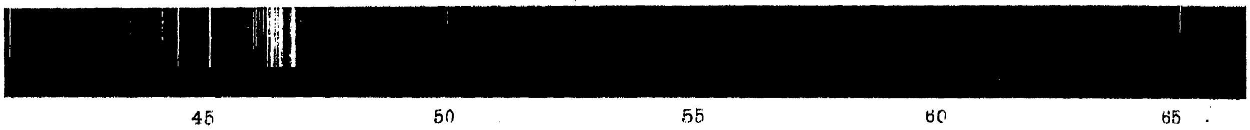
92
Kohle
Funke in Leuchtgas
arbon Spark in Coalgas
rbon Étincelle dans gaz.



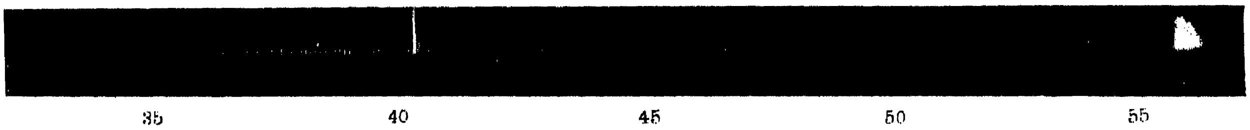
93
dium Jndium
Arc. Bogen



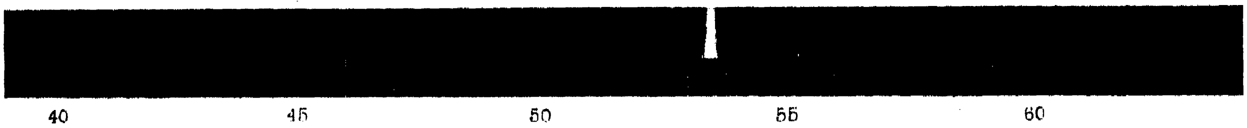
94
Spark Funke
Étincelle.



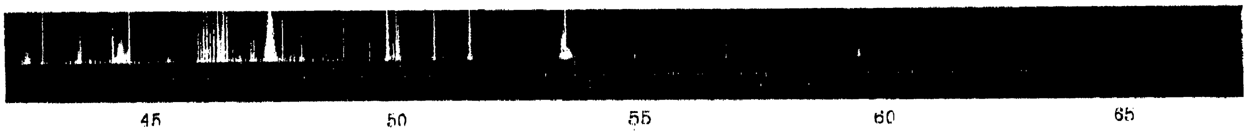
95
nganese Mangan
lame Flamme
Manganèse



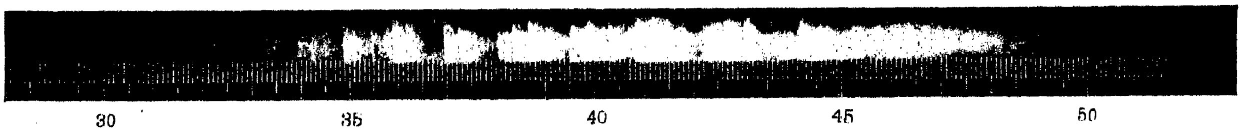
96
allium Thallium
Arc. Bogen



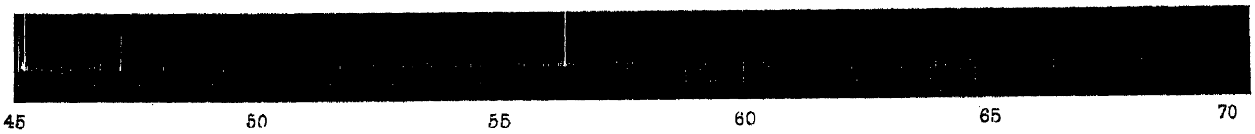
97
Spark Funke
Étincelle.



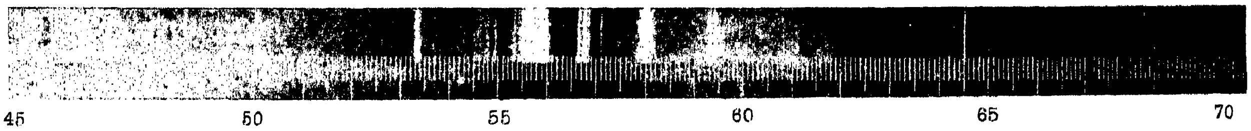
98
Tin Zinn
lame Flamme
Etain



99
Arc. Bogen

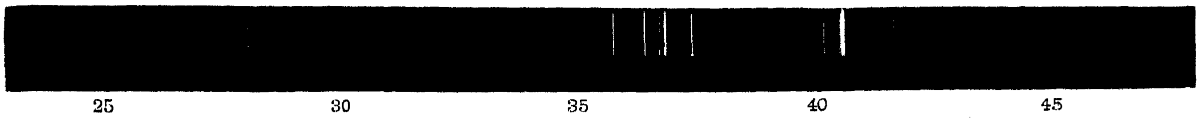


100
Spark Funke
Étincelle

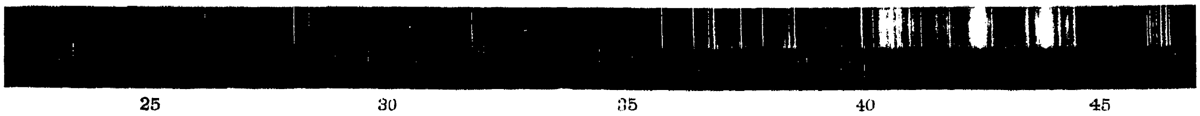


XI. Pb. As. Sb. Bi. Si.

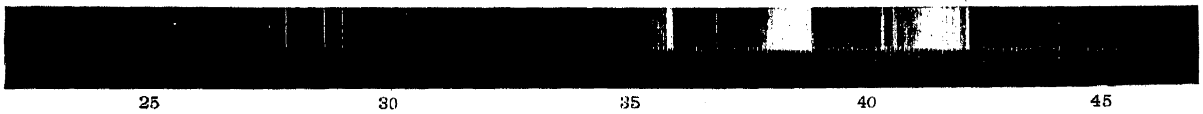
101
Lead *Blei*
Arc *Bogen*
Plomb Arc



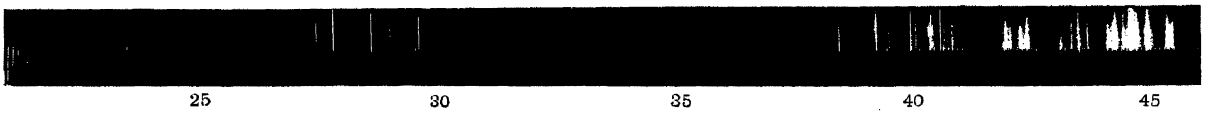
102
Spark *Funke*
Étincelle



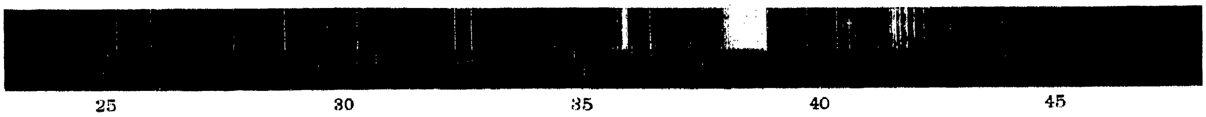
103
Arsenic *Arsen*
Arc *Bogen*



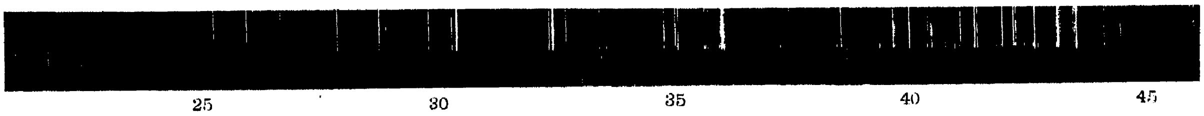
104
Spark *Funke*
Étincelle



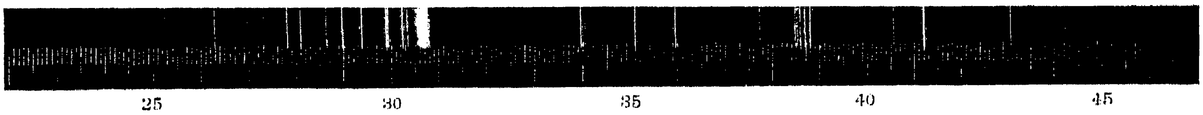
105
Antimony *Antimon*
Arc *Bogen*
Antimoine Arc



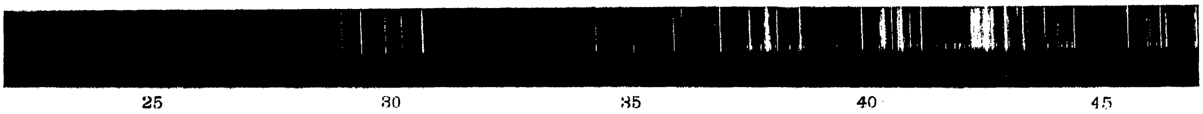
106
Spark *Funke*
Étincelle



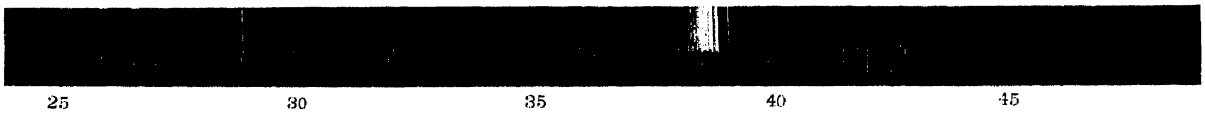
107
Bismuth *Wismuth*
Arc *Bogen*



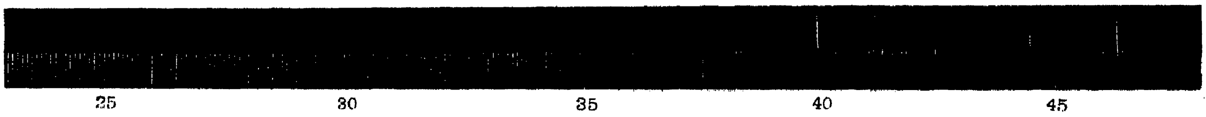
108
Spark *Funke*
Étincelle



109
Silicon *Silicium*
Arc *Bogen*
Silicium Arc



110
Spark *Funke*
Étincelle

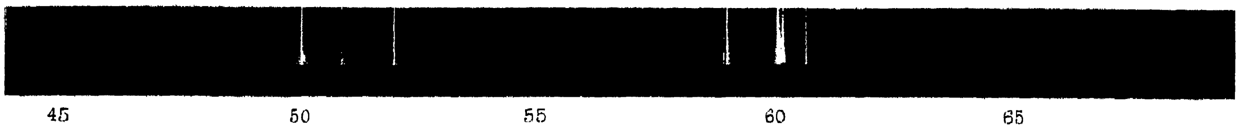


Gustav Fischer, Jena.

XII. Pb. As. Sb. Bi.

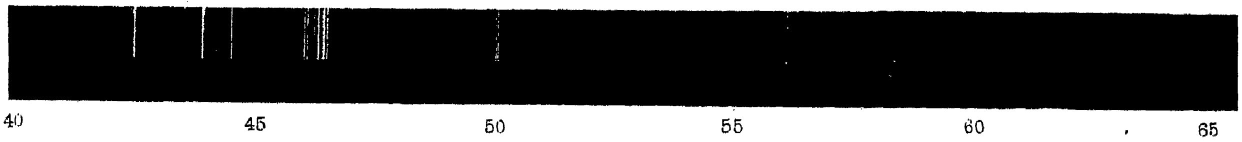
111

Lead *Blei*
Arc *Bogen*
Plomb Arc



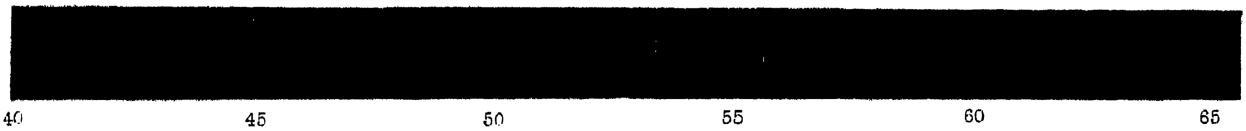
112

Spark *Funke*
Étincelle



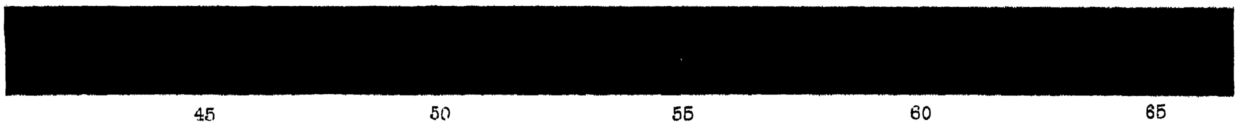
113

Arsenic *Arsen*
uumtube *Vakuumröhre*
Tube Geissler



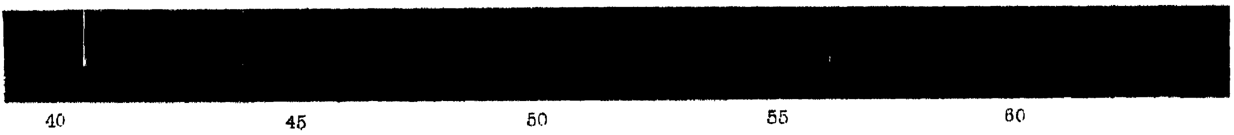
114

Spark *Funke*
Étincelle



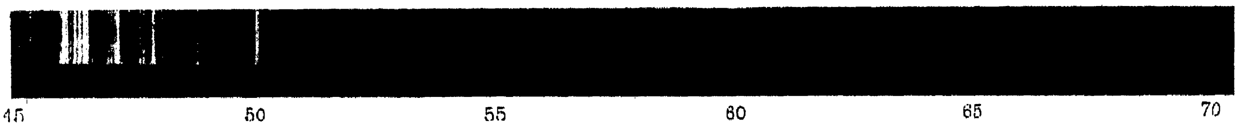
115

Lead *Blei*
nduction Funke (Selbstinduction)
lomb Étincelle avec S.I.



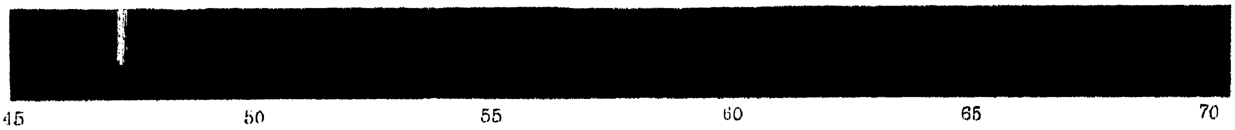
116

ntimony *Antimon*
Spark *Funke*
ntimonie *Étincelle*



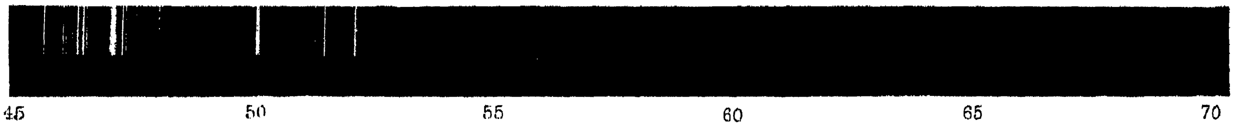
117

ismuth *Wismuth*
Arc *Bogen*



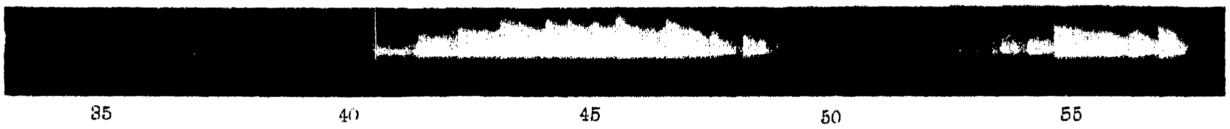
118

Spark *Funke*
Étincelle



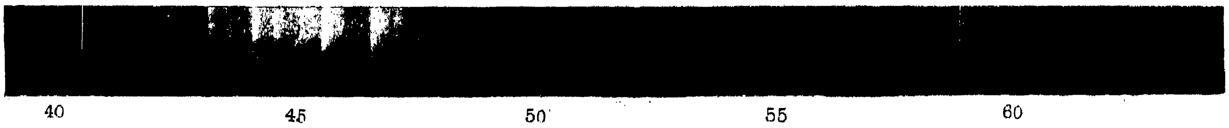
119.

Lead *Blei*
Flame *Flamme*
Plomb Flamme



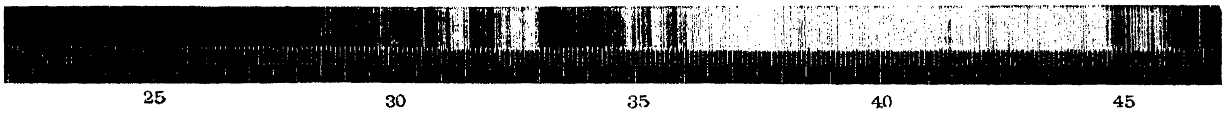
120

Flame *Flamme*

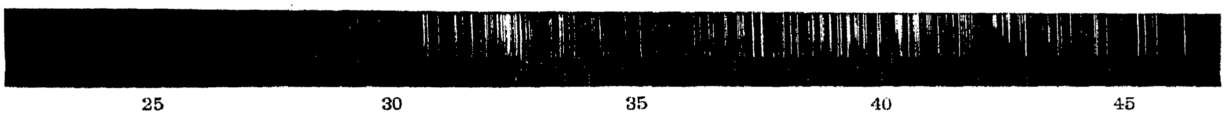


XIII. Nb. Zr. Y. La. Yb.

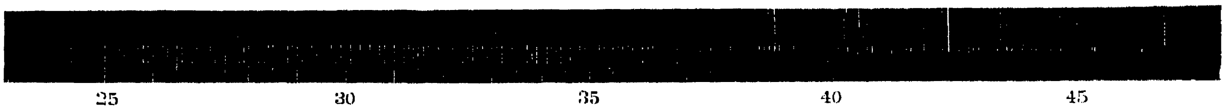
121
Niobium Niob
Arc Bogen



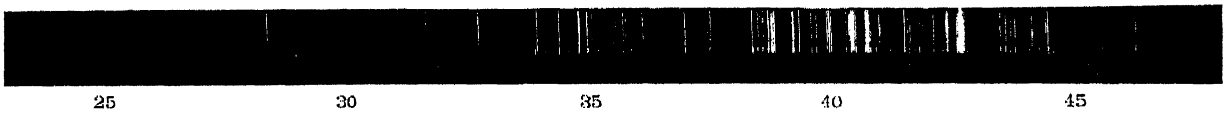
122
Spark Funke
Étincelle



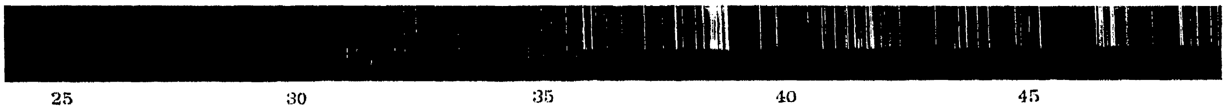
123
Zirconium Zirkon
Arc Bogen
Zircone Arc



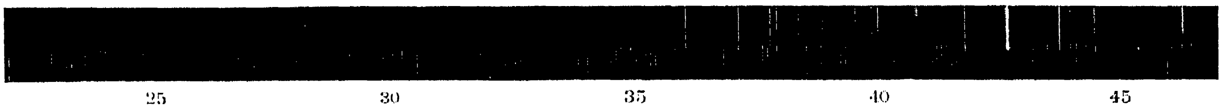
124
Spark Funke
Étincelle



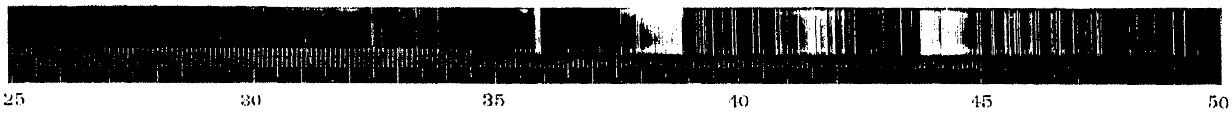
125
Yttrium Yttrium
Arc Bogen



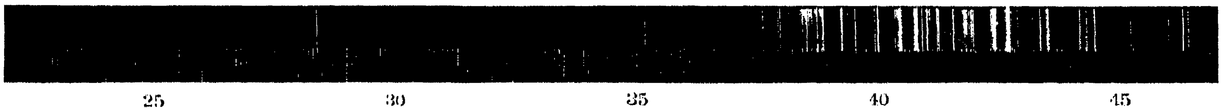
126
Spark Funke
Étincelle



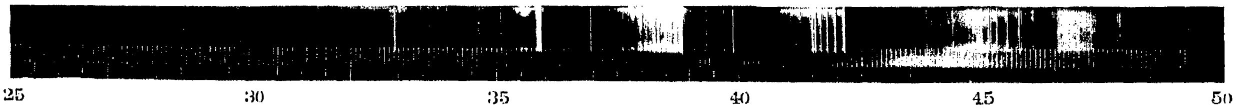
127
Lanthanum Lanthan
Arc Bogen
Lanthane Arc



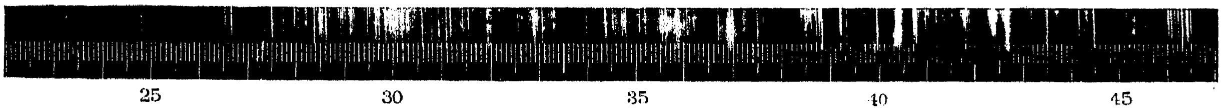
128
Spark Funke
Étincelle



129
Ytterbium Ytterbium
Arc Bogen



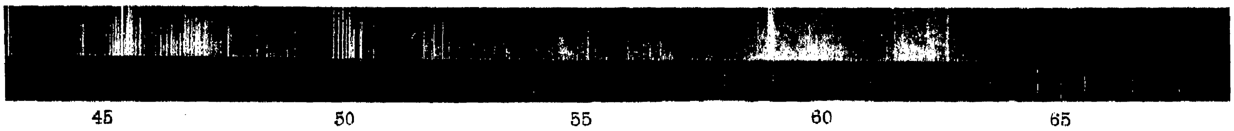
130
Spark Funke
Étincelle



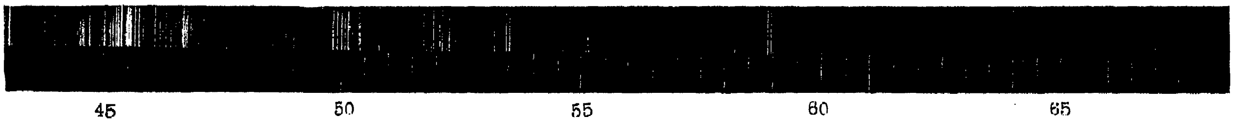
Gustav Fischer, Jena

XIV Nb. Zr. Y. La. Yb.

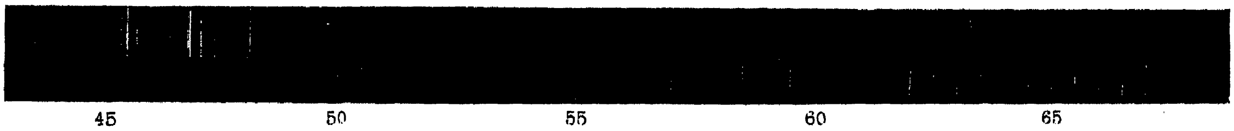
131
Niobium *Niob*
Arc. *Bogen*



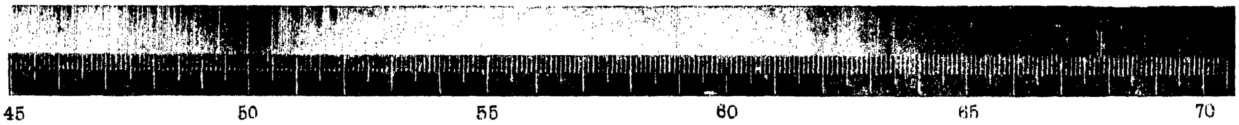
132
Spark *Funke*
Étincelle



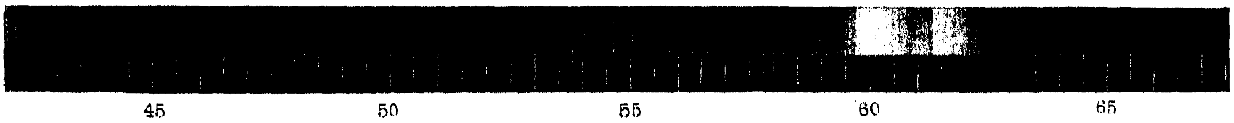
133
Zirconium. *Zirkon.*
Arc *Bogen*
Zircone Arc.



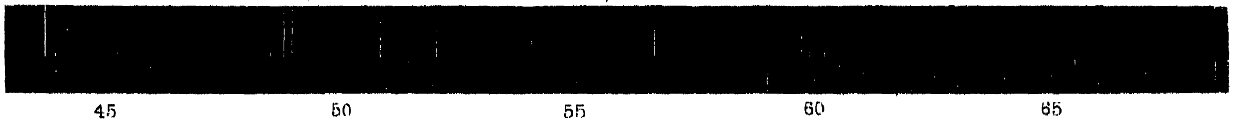
134
Spark *Funke*
Étincelle



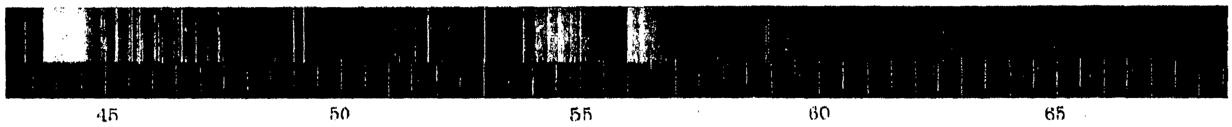
135
Yttrium *Yttrium*
Arc *Bogen*



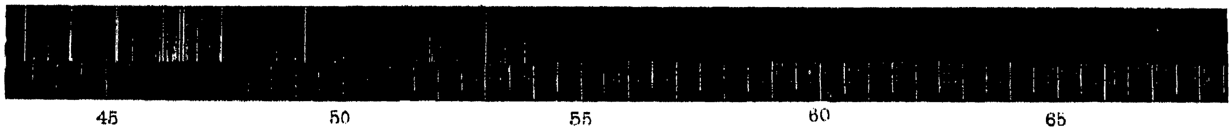
136
Spark *Funke*
Étincelle



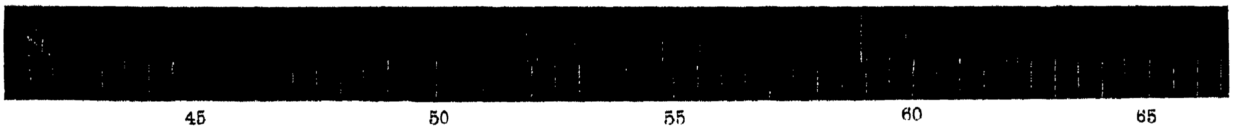
137
anthanum *Lanthan*
Arc *Bogen*
Lanthane Arc



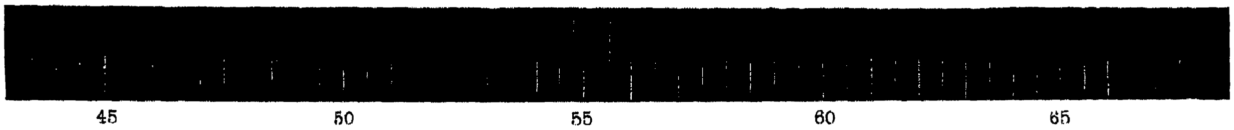
138
Spark *Funke*
Étincelle



139
Ytterbium *Ytterbium*
Arc *Bogen*

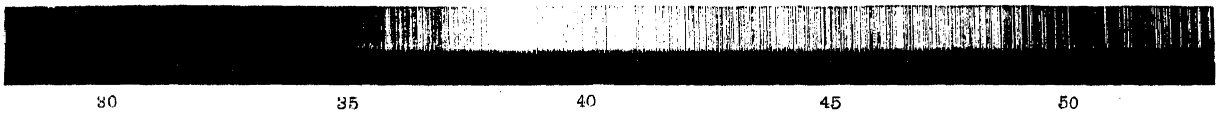


140
Spark *Funke*
Étincelle

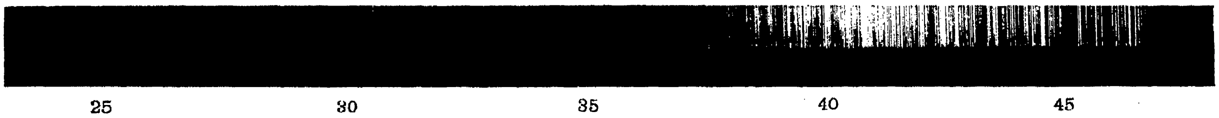


XV. Ce. Pr. Nd. Sa. Gd. Ho. Er.

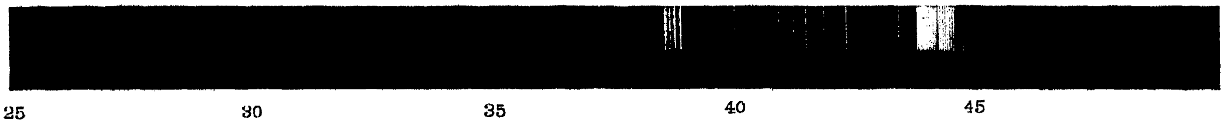
141
Cerium *Arc* — *Cer* *Bogen* — *Cerium Arc*



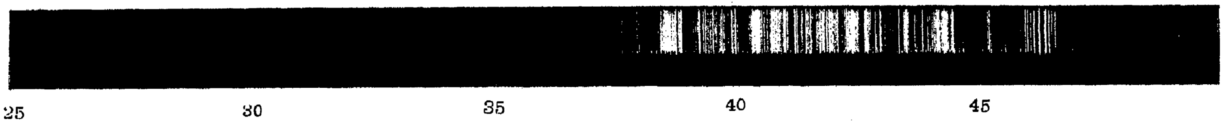
142
Spark — *Funke* — *Étincelle*



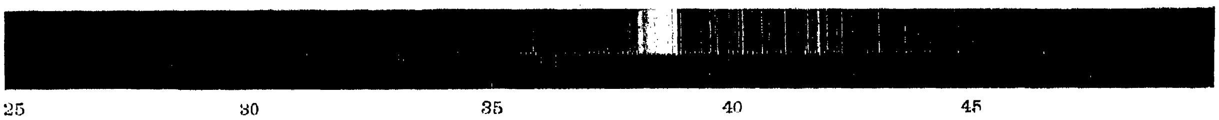
143
aseodymium *Arc* — *Praseodym* *Bogen* — *Praseodyme Arc*



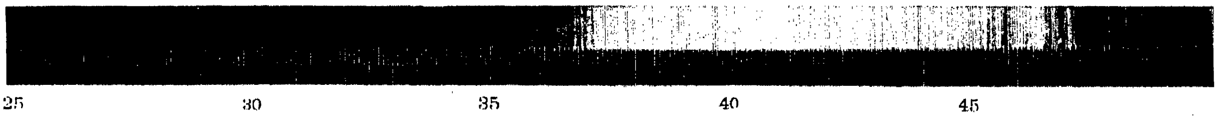
144
Spark — *Funke* — *Étincelle*



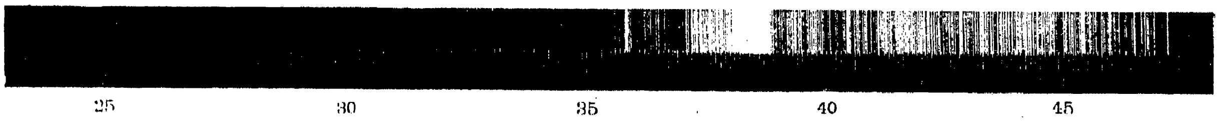
145
eodymium *Arc* — *Neodym* *Bogen* — *Néodyme Arc*



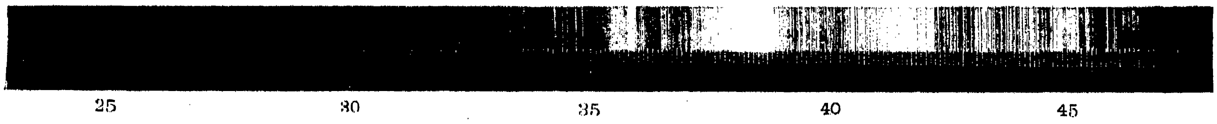
146
Spark — *Funke* — *Étincelle*



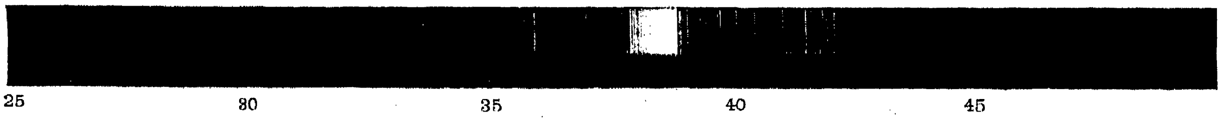
147
Samarium *Arc* — *Samarium* *Bogen*



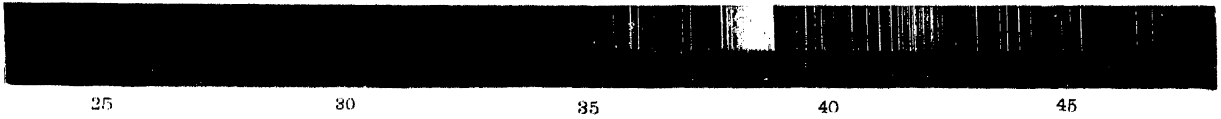
148
adolinium *Arc* — *Gadolinium* *Bogen*



149
Holmium *Arc* — *Holmium* *Bogen*



150
Erbium *Arc* — *Erbium* *Bogen*



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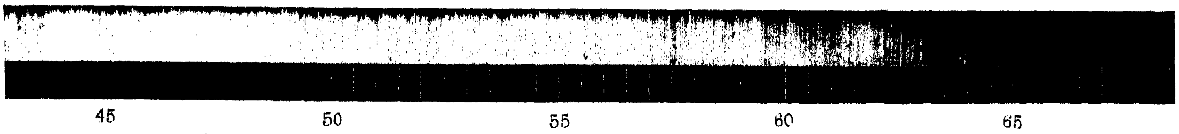
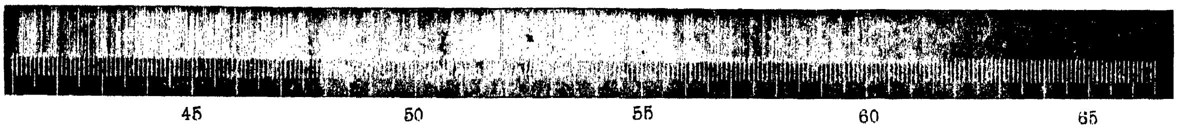
151

Cerium *Cer*
Arc *Bogen*
Cérium Arc



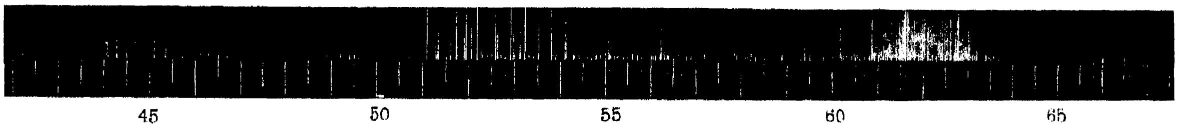
152

Spark *Funke*
Étincelle



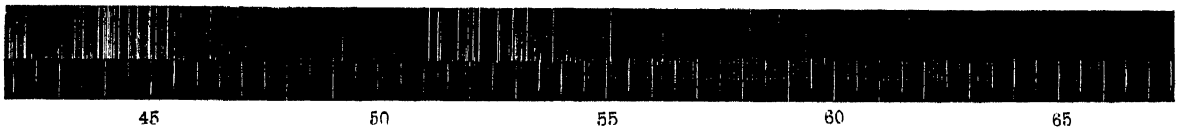
153

Praseodymium *Praseodym*
Arc *Bogen*
Praséodyme Arc



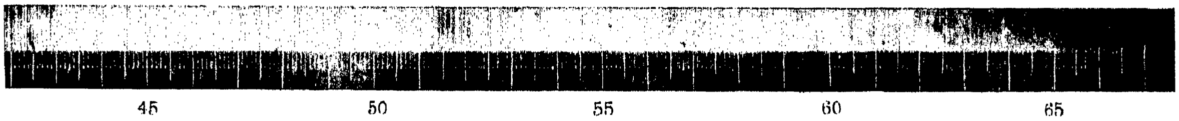
154

Spark *Funke*
Étincelle



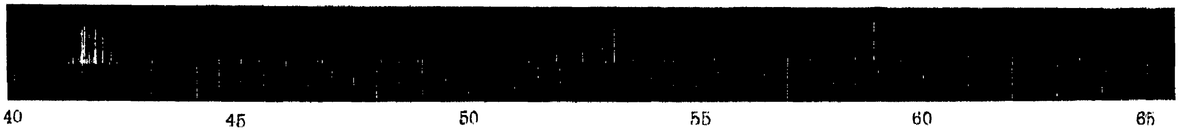
155

Neodymium *Neodym*
Arc *Bogen*
Néodyme Arc



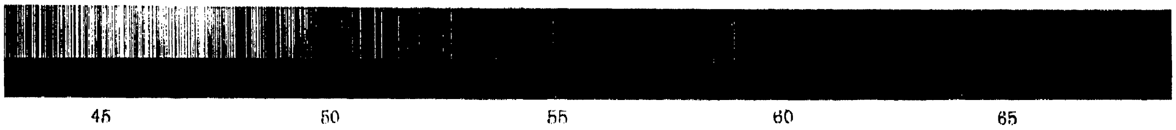
156

Spark *Funke*
Étincelle



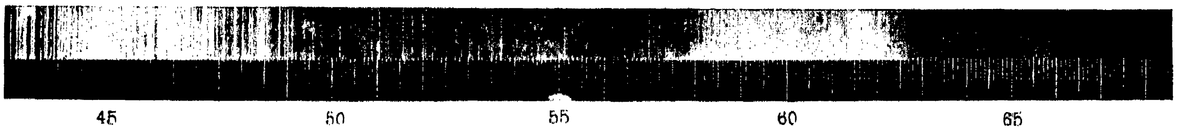
157

Samarium *Samarium*
Arc *Bogen*



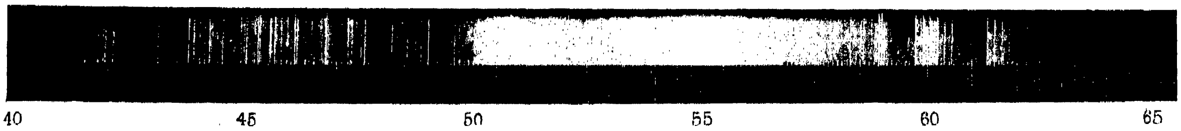
158

Gadolinium *Gadolinium*
Arc *Bogen*



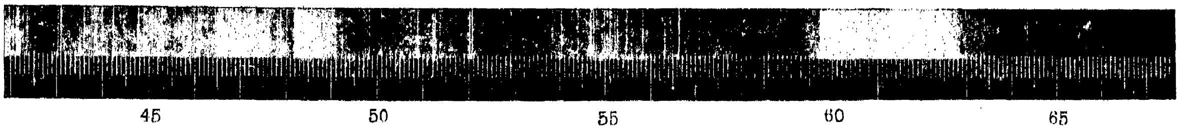
159

Holmium *Holmium*
Arc *Bogen*



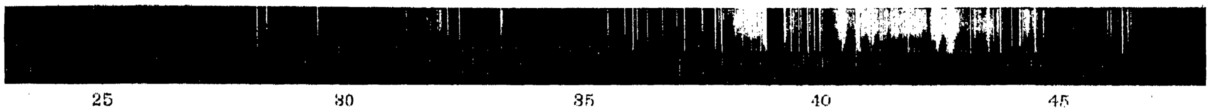
160

Erbium *Erbium*
Arc *Bogen*

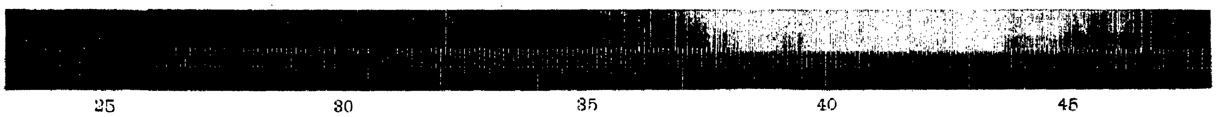


XVII. Er. Wo. Th. U. Mo. Ti.

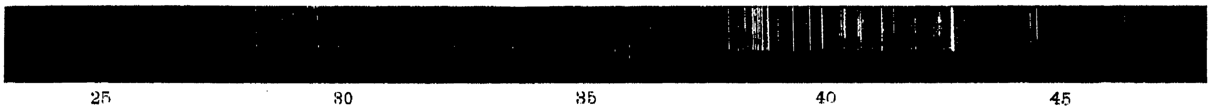
161
Erbium *Erbium*
Spark *Funke*
Étincelle



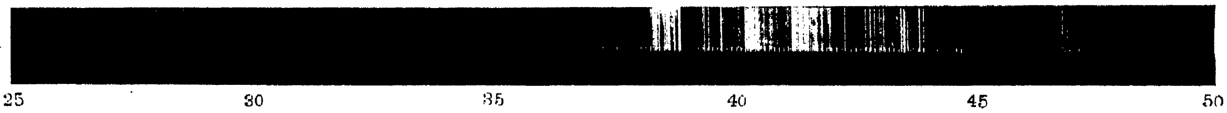
162
Tungsten *Wolfram*
Arc *Bogen*
Wolfram Arc



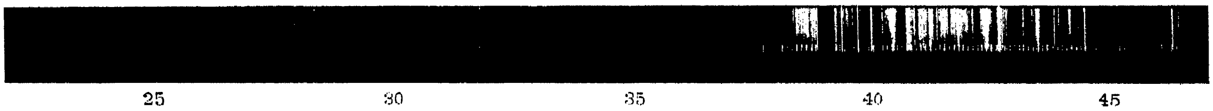
163
Spark *Funke*
Étincelle



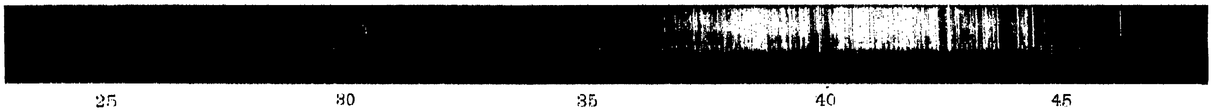
164
Thorium *Thor*
Arc *Bogen*



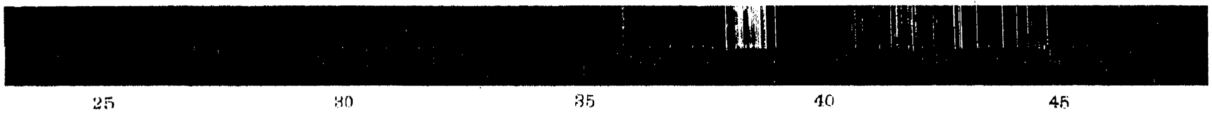
165
Spark *Funke*
Étincelle



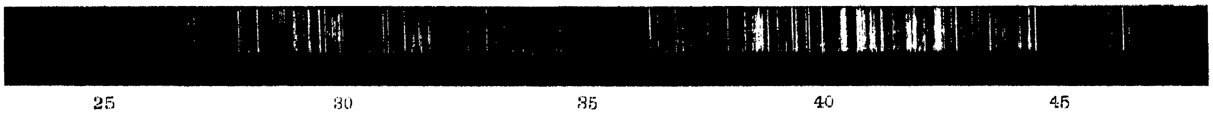
166
Uranium *Uran*
Spark *Funke*
Uranium Étincelle



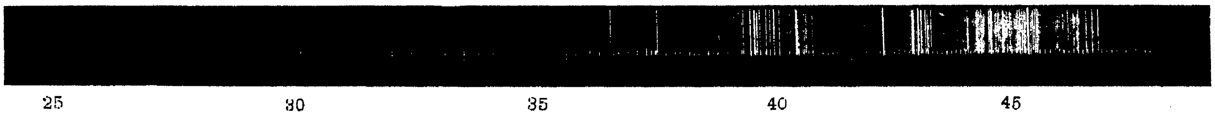
167
Molybdenum *Molybdän*
Arc *Bogen*
Molybdène Arc



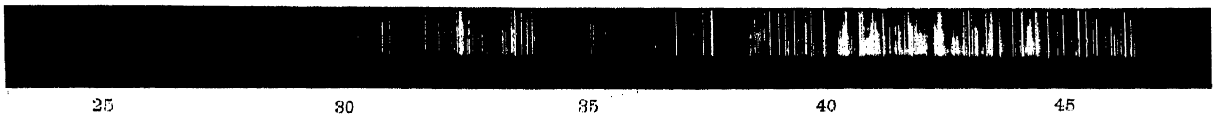
168
Spark *Funke*
Étincelle



169
Titanium *Titan*
Arc *Bogen*
Titane Arc



170
Spark *Funke*
Étincelle



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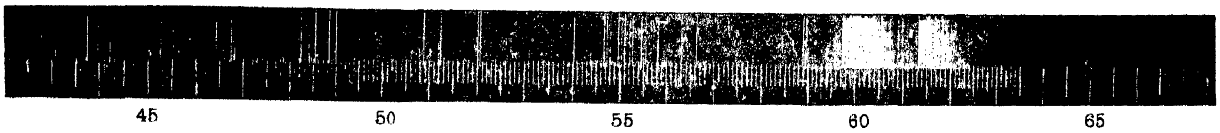
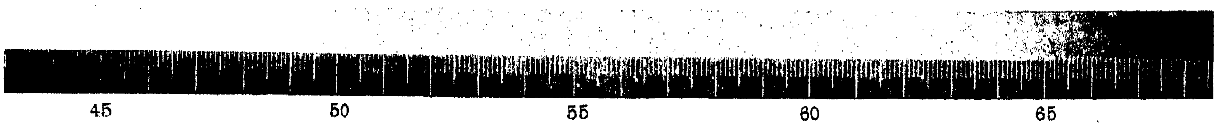
171

Erbium *Erbium*
Arc *Bogen*



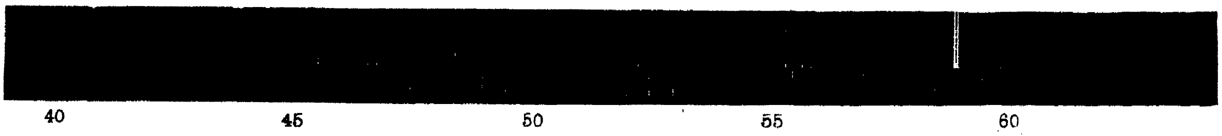
172

Tungsten *Wolfram*
Arc *Bogen*
Wolfram Arc



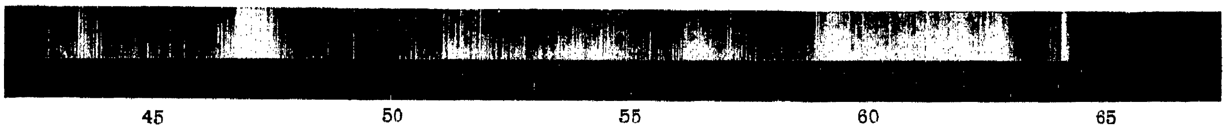
173

Spark *Funke*
Étincelle



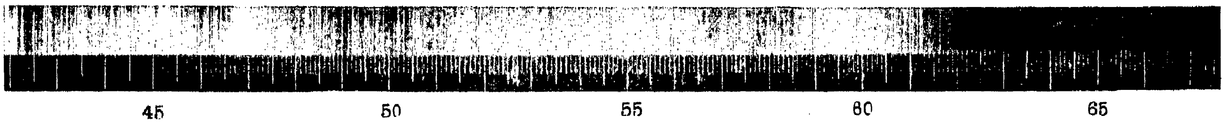
174

Thorium *Thor*
Arc *Bogen*



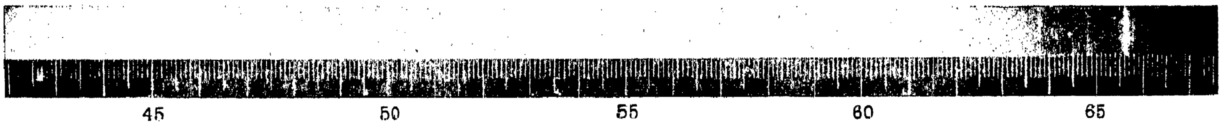
175

Spark *Funke*
Étincelle



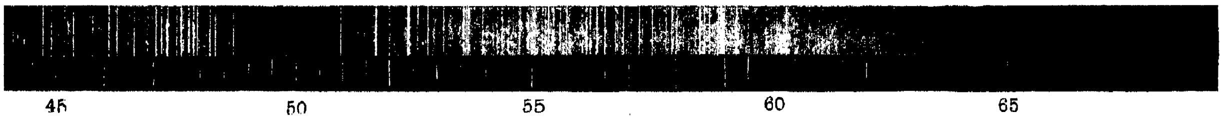
176

Uranium *Uran*
Spark *Funke*
Uranium *Étincelle*



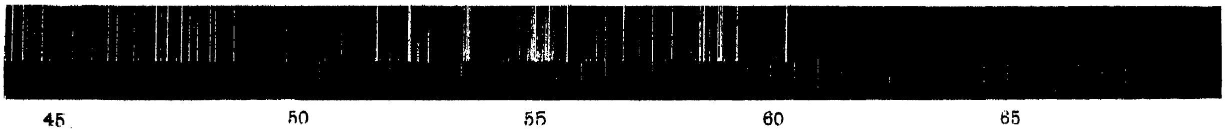
177

olybdenum *Molybdän*
Arc *Bogen*
Molybdène Arc



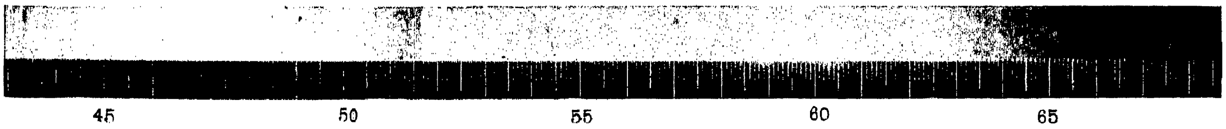
178

Spark *Funke*
Étincelle



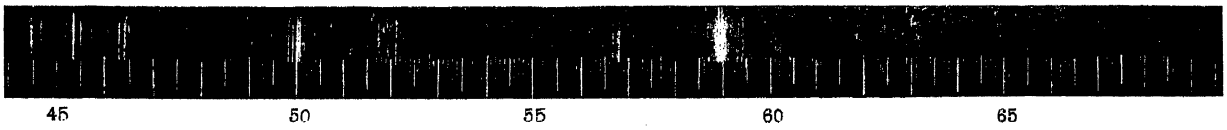
179

Titanium *Titan*
Arc *Bogen*
Titane Arc



180

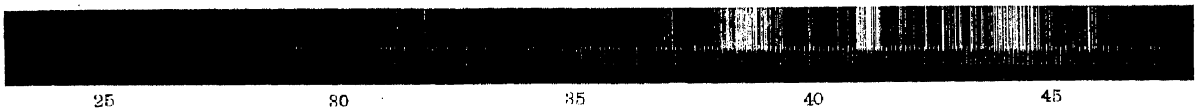
Spark *Funke*
Étincelle



XIX. Va. Cr. Mn. Fe. Co.

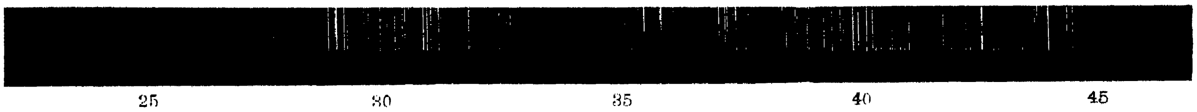
181

Vanadium Arc
Vanadium Bogen



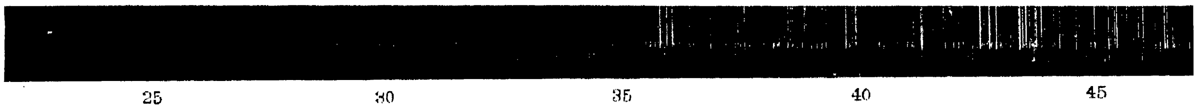
182

Spark
Funke
Étincelle



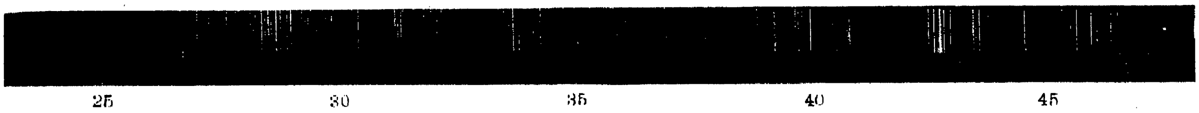
183

Chromium Arc
Chrom Bogen
Chrome Arc



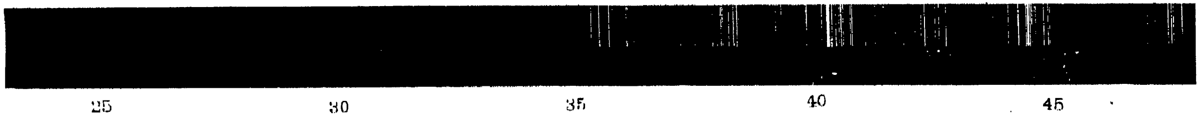
184

Spark
Funke
Étincelle



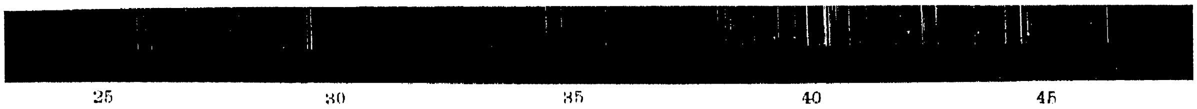
185

Manganese Arc
Mangan Bogen
Manganèse Arc



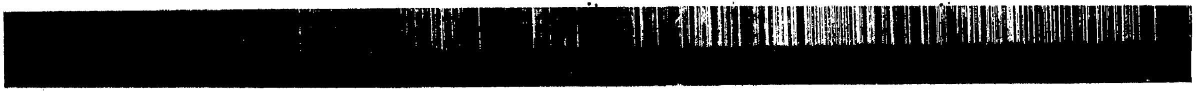
186

Spark
Funke
Étincelle



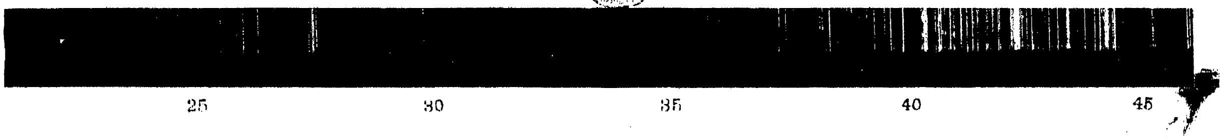
187

Iron Arc
Eisen Bogen
Fer Arc



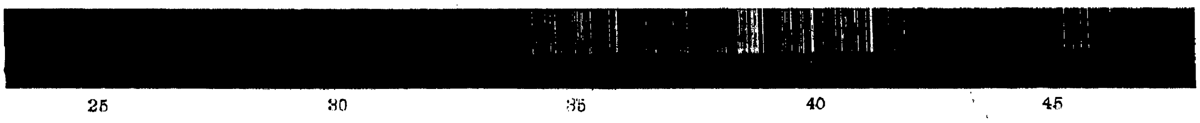
188

Spark
Funke
Étincelle



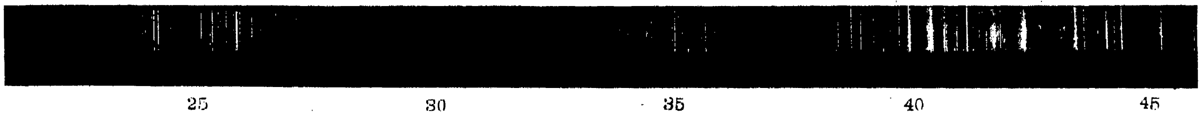
189

Cobalt Arc
Cobalt Bogen



190

Spark
Funke
Étincelle



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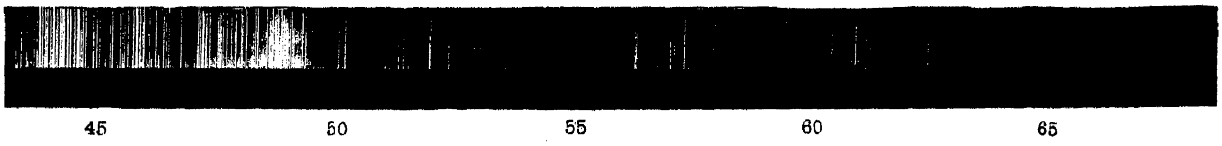
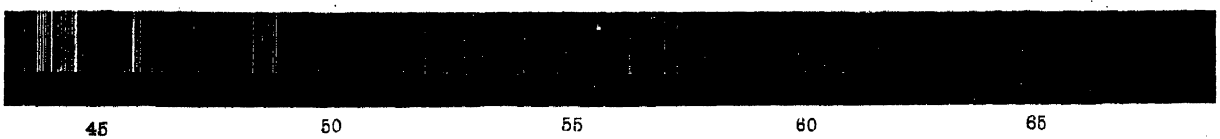
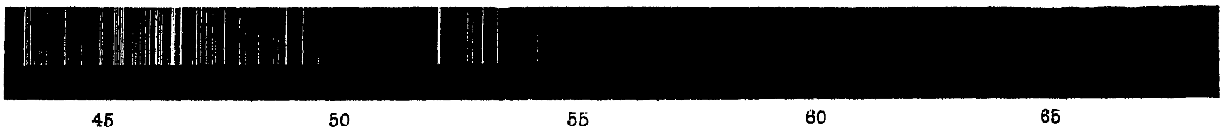
191
Vanadium Vanadium
Arc Bogen



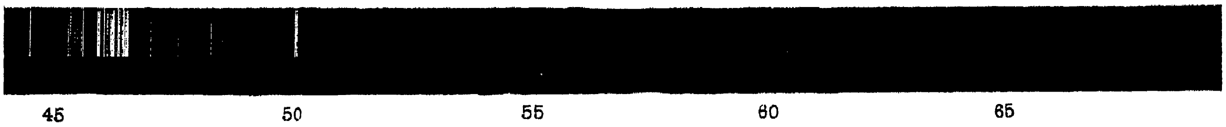
192
Spark Funke
Étincelle



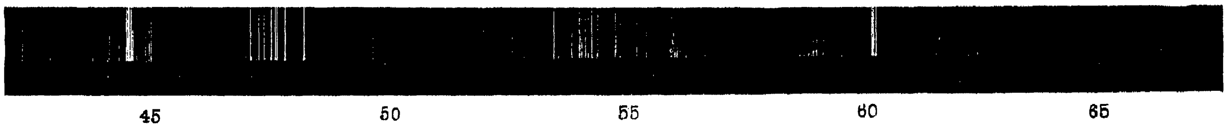
193
Chromium Chrom
Arc Bogen
Chrome Arc



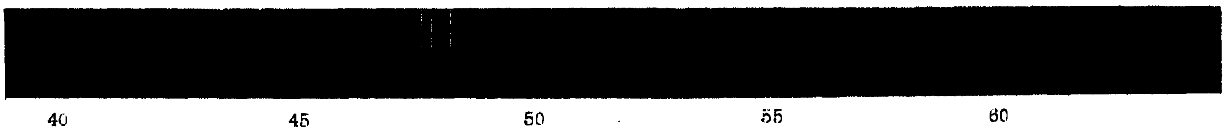
194
Spark Funke
Étincelle



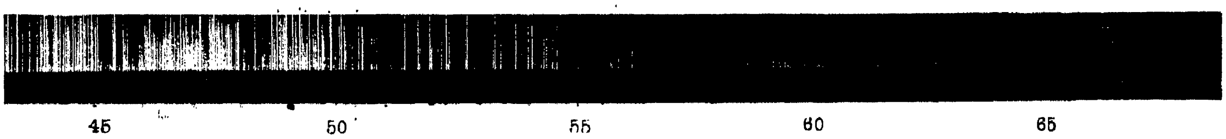
195
Manganese Mangan
Arc Bogen
Manganèse Arc



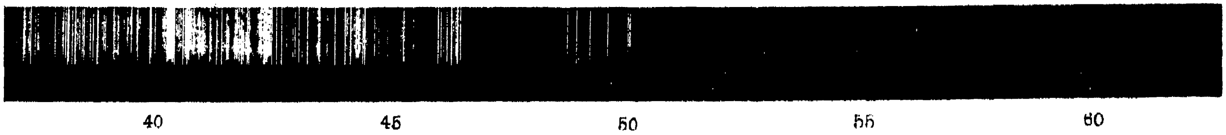
196
Spark Funke
Étincelle



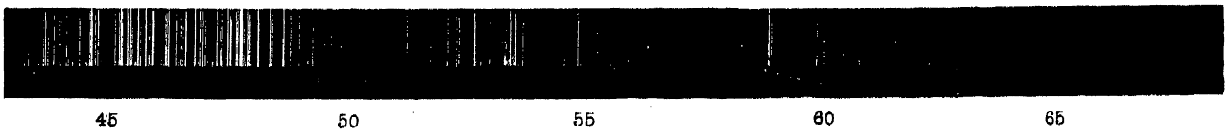
197
Iron Eisen
Arc Bogen
Fer Arc



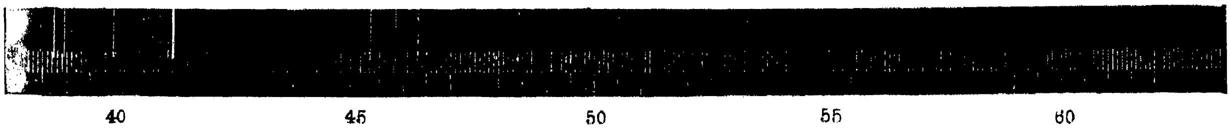
198
Spark Funke
Étincelle



199
Cobalt Cobalt
Arc Bogen

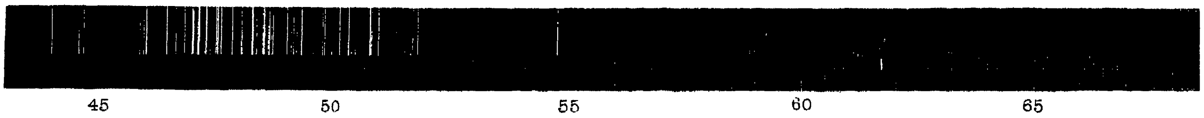


200
Spark Funke
Étincelle

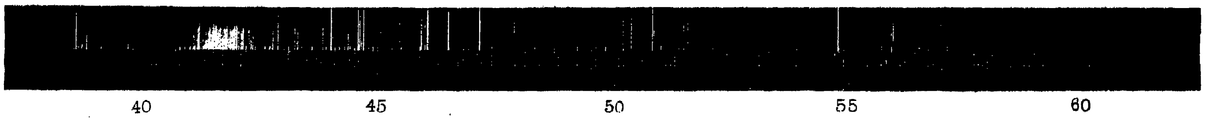


XXII. Ni. Ru. Rh. Pd. Os. Jr. Pt.

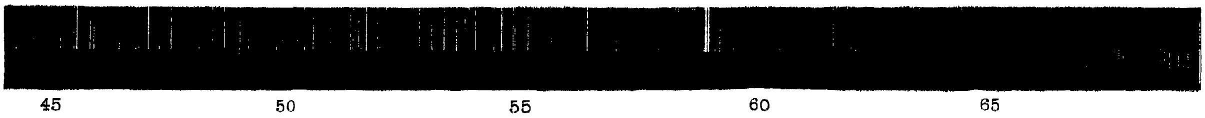
211
Nickel *Nickel*
Arc *Bogen*



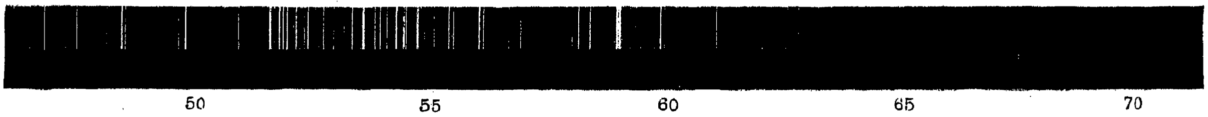
212
Spark *Funke*
Étincelle



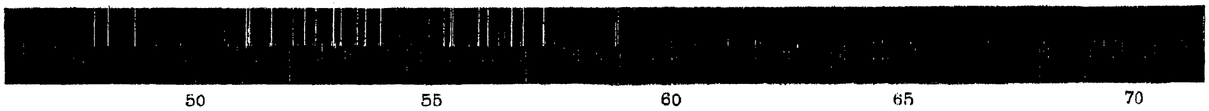
213
uthénium *Ruthenium*
Arc *Bogen*



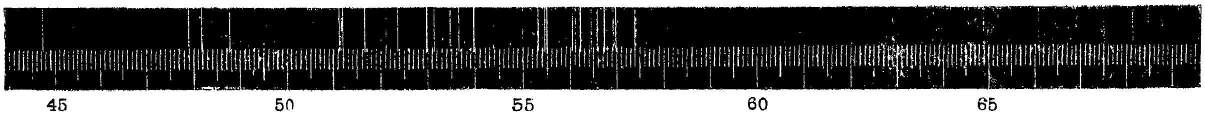
214
Rhodium *Rhodium*
Arc *Bogen*



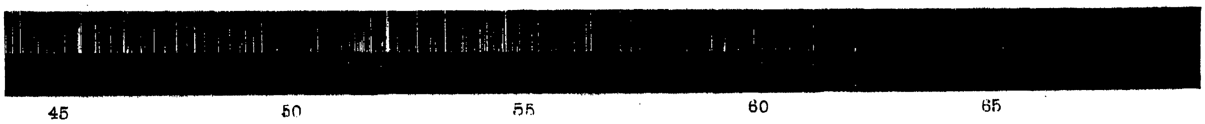
215
lladium *Palladium*
Arc *Bogen*



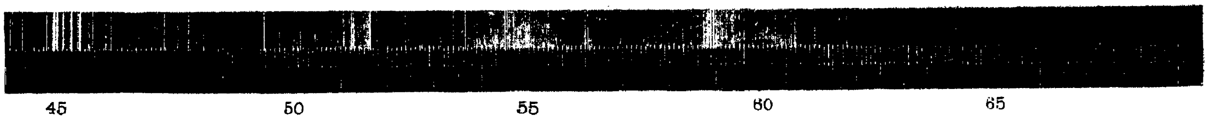
216
Spark *Funke*
Étincelle



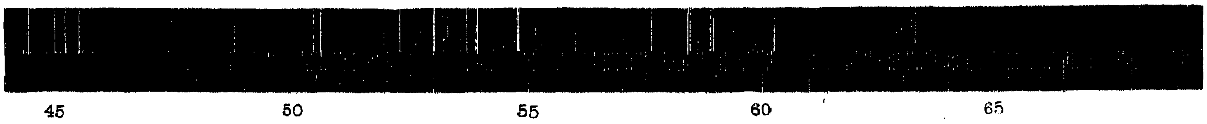
217
Osmium *Osmium*
Arc *Bogen*



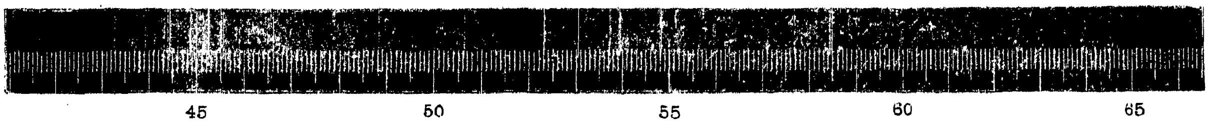
218
Jridium *Jridium*
Arc *Bogen*



219
Platin *Platin*
Arc *Bogen*
Platine Arc



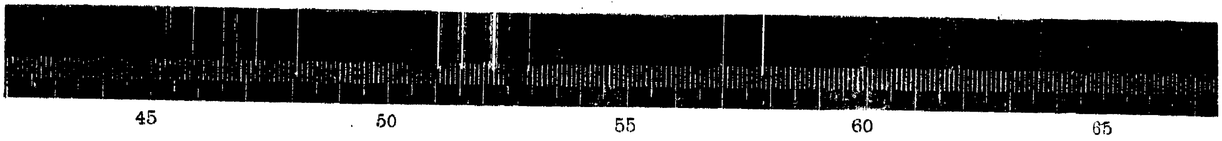
220
Spark *Funke*
Étincelle



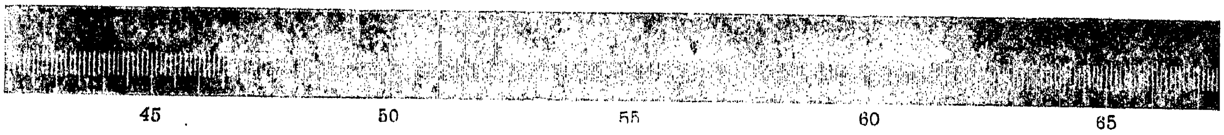
Gustav Fischer, Jena.

XXIV. Cu. Ag. Au. Pt. N.

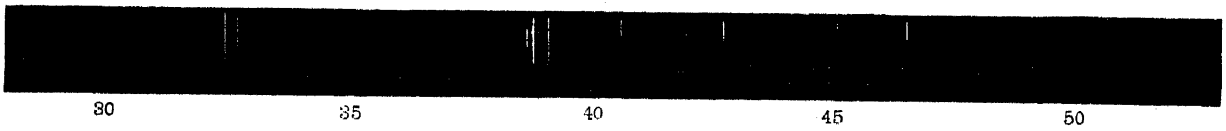
231
Copper Kupfer
Arc Bogen
Cuivre Arc



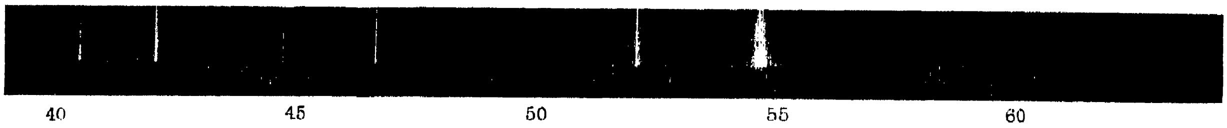
232
Spark Funke
Étincelle



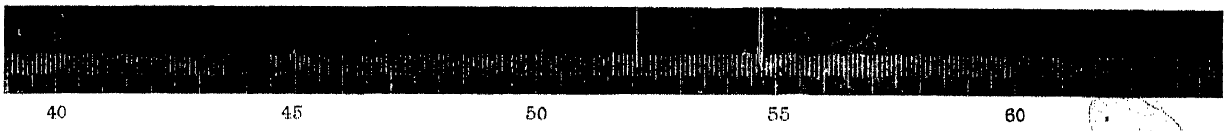
233
Spark Funke
(with N) (mit N)
Étincelle (avec N)



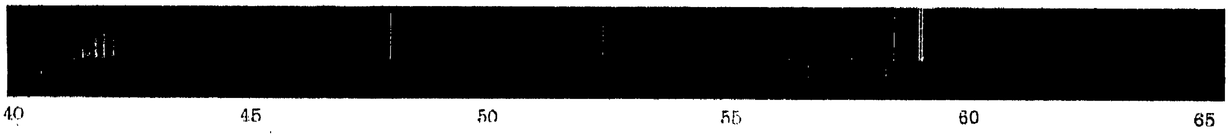
234
Silver Silber
Arc Bogen
Argent Arc



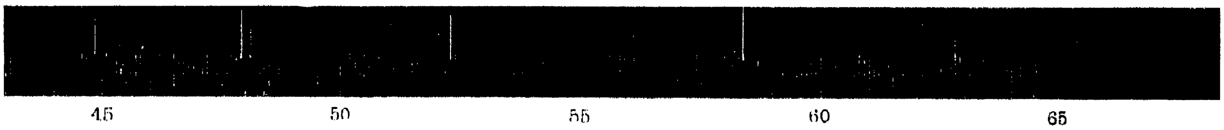
235
Spark Funke
Étincelle



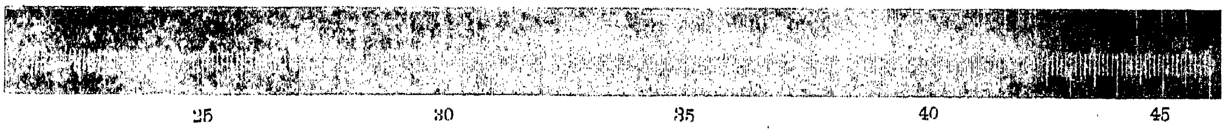
236
Gold Gold
Arc Bogen
Or Arc



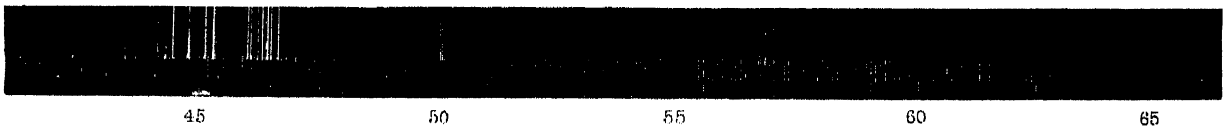
237
Spark Funke
Étincelle



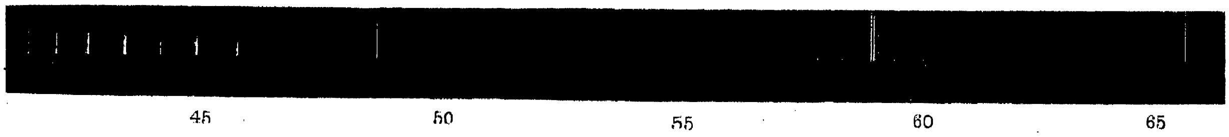
238
Platinum Platin
Funke mit Selbstinduction
Spark with self-induction
Platine Étincelle avec S.I.



239
Air Luft
Spark Funke
Air Étincelle

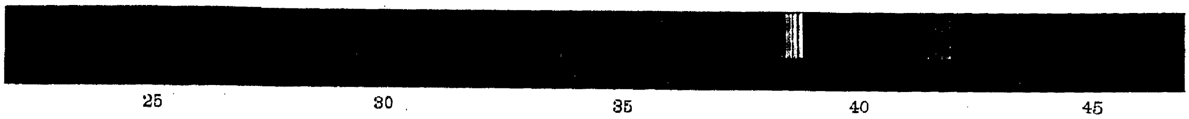


240
Nitrogen Stickstoff
nd Spectrum Banden
Azote Bandes

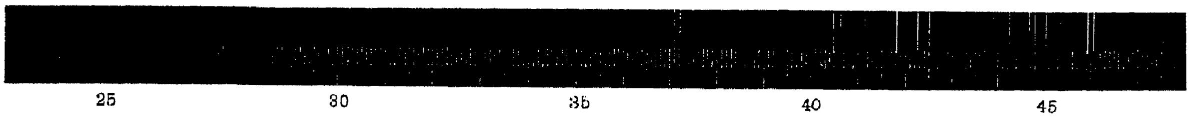


XXV. P. O. S. Se. Te. Cl. Br.

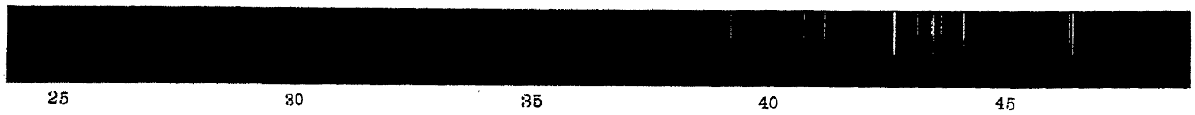
241
Phosphorus Arc *Phosphor Bogen*
Phosphore Arc



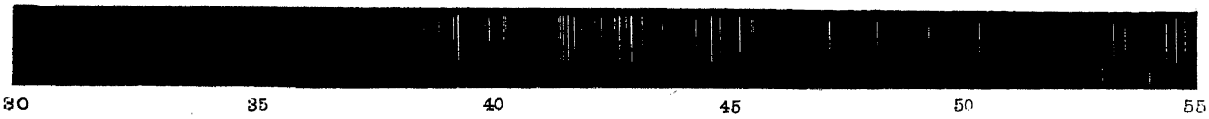
242
Vacuum Tube *Vacuum-Röhre*
Tube Geissler



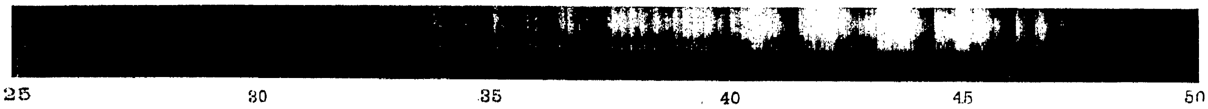
243
Oxygen *Sauerstoff*
Oxygène



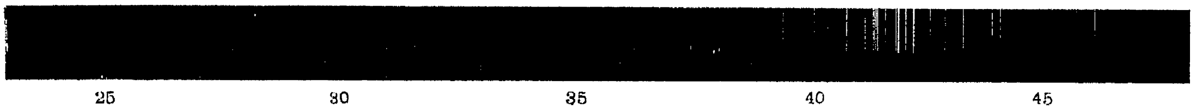
244
Sulphur Line Spectrum *Schwefel Linien*
Soufre Lignes



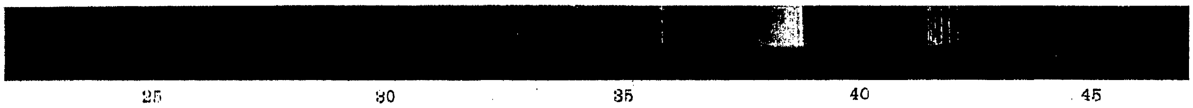
245
Band Spectrum *Banden*
Bandes



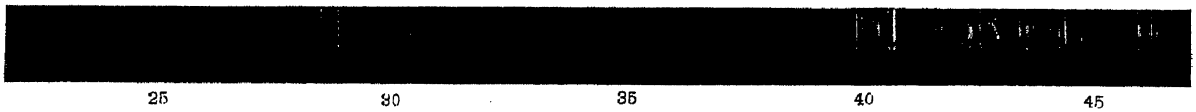
246
Selenium *Selen*
Sélénium



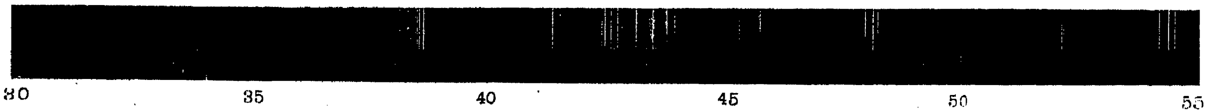
247
Tellurium Arc *Tellur Bogen*
Tellure Arc



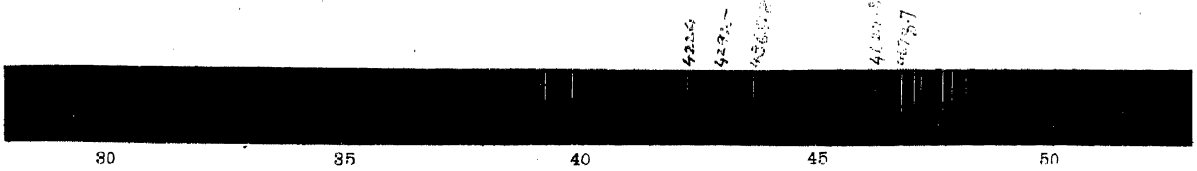
248
Spark *Funke*
Étincelle



249
Chlorine *Chlor*
Chlore

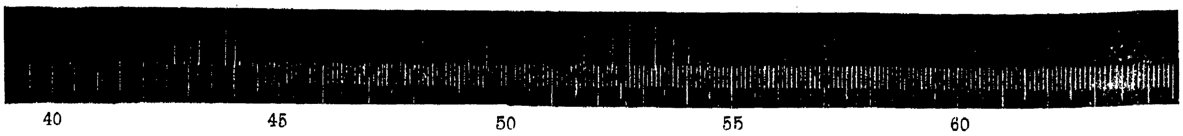


250
Bromine *Brom*
Brome

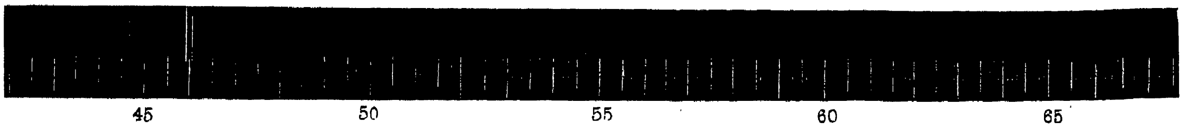


Gustav Fischer, Jena.

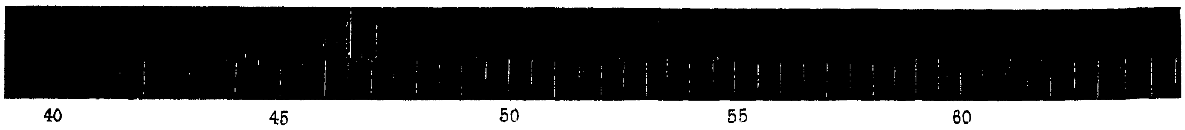
XXVI. Fe. P. O. S. Se. $SnCl_4$. Cl. Br.



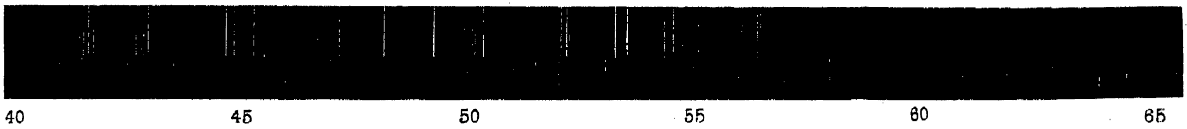
251
Iron *Eisen*
Spark with *Funke mit*
induction *Selbstinduction*
Fer. Étincelle avec S.I.



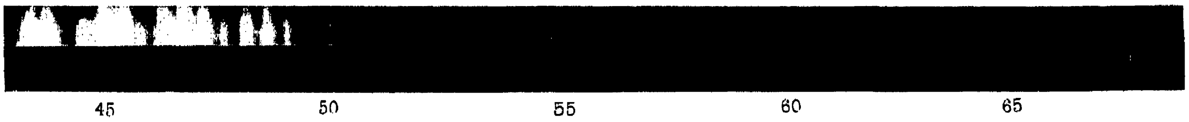
252
Phosphorus *Phosphor*
Vacuum Tube *Vacuumröhre*
Phosphore Tube Geissler



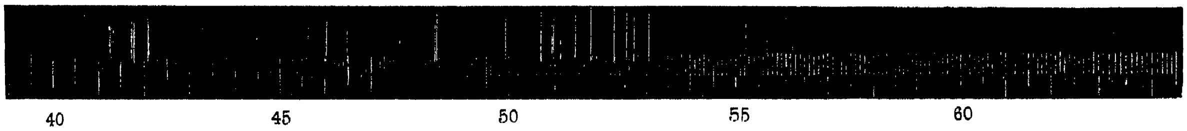
253
Oxygen *Sauerstoff*
Oxygène



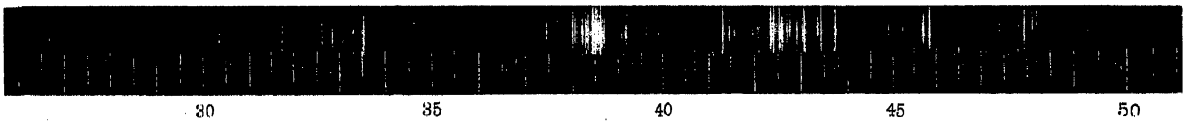
254
Sulphur *Schwefel*
Line Spectrum *Linien*
Soufre Lignes



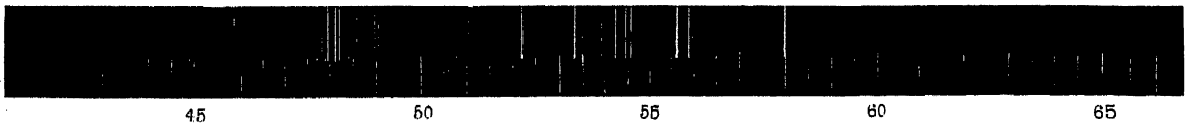
255
Band Spectrum *Banden*
Bandes



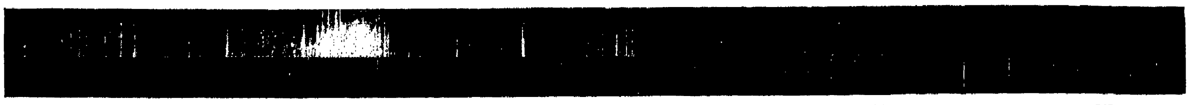
256
Selenium *Selen*
Line Spectrum *Linien*
Sélénium Lignes



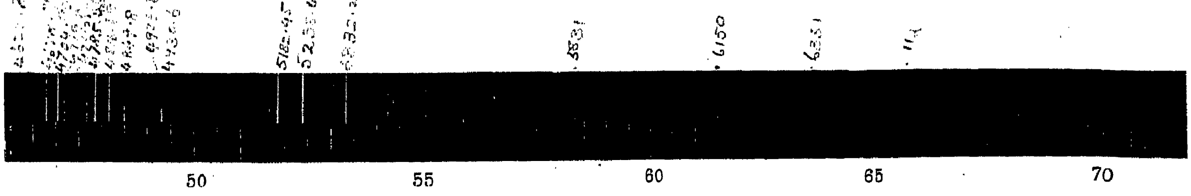
257
$SnCl_4$ *$SnCl_4$*
Vacuum Tube *Vacuumröhre*
Tube Geissler



258
$SnCl_4$ *$SnCl_4$*
Vacuum Tube *Vacuumröhre*
Tube Geissler



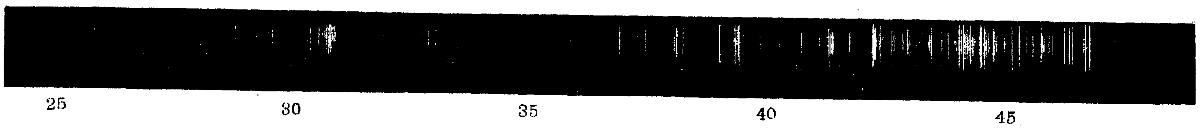
259
Chlorine *Chlor*
Chlore



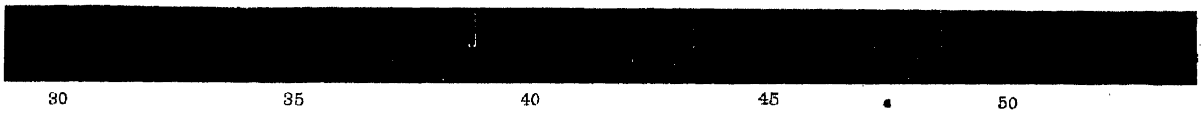
260
Bromine *Brom*
Brome

XXVII. J. H. He. A. C. Sonne.

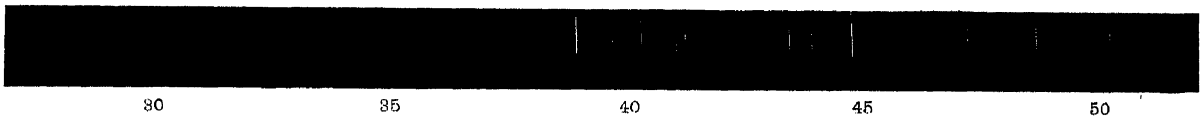
261
Iodine *Jod*
Iode



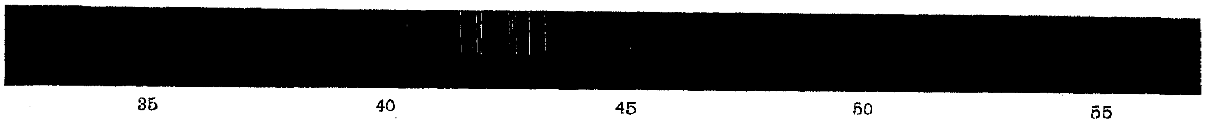
262
Hydrogen *Wasserstoff*
Hydrogène



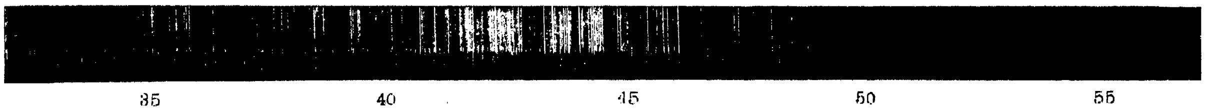
263
Helium *Helium*
Hélium



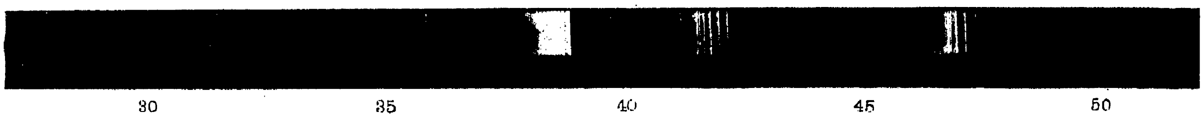
264
Argon *Argon*
Red Spectrum *rotes Sp.*
Sp. rouge



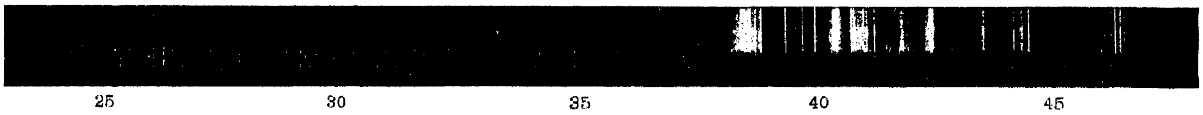
265
Argon *Argon*
Blue Spectrum *blaues Sp.*
Sp. bleu



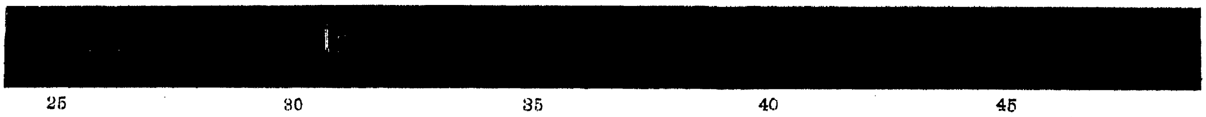
266
Carbon *Kohle*
Arc *Bogen*
Charbon Arc



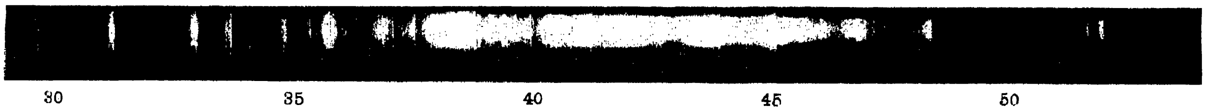
267
Spark *Funke*
Étincelle



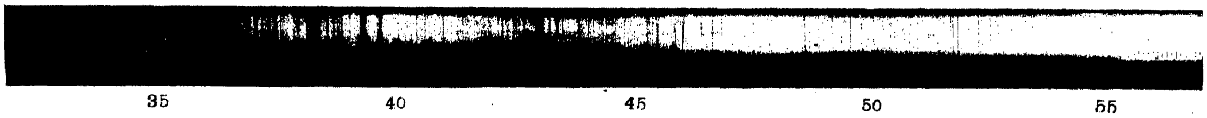
268
Coalgas *Leuchtgas*
Flame *Flamme*
Flamme du gaz d'éclairage



269
arbon Monoxide *Kohlenoxyd*
Oxyde de Carbone



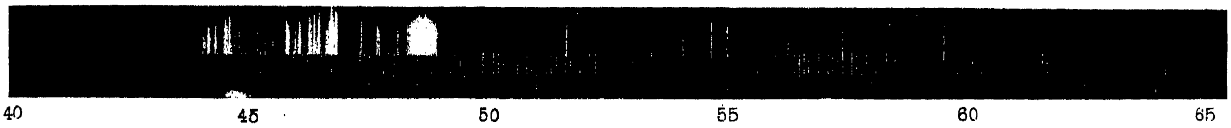
270
Sun *Sonne*
Soleil



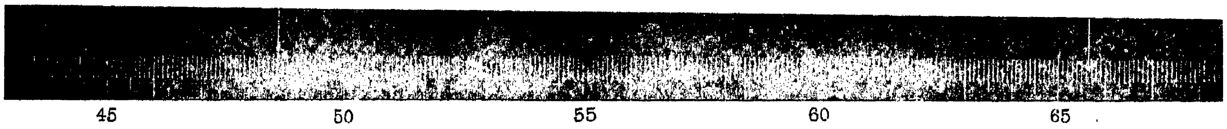
Gustav Fischer, Jena.

XXVIII J. H. He. A. C. Luft. CO. Sonne.

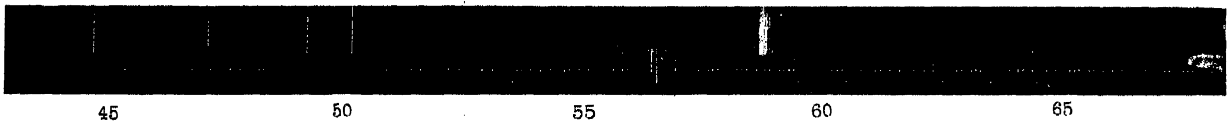
271
Iodine *Jod*
Iode



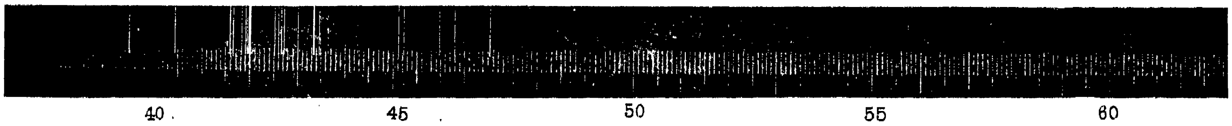
272
Hydrogen *Wasserstoff*
Hydrogène



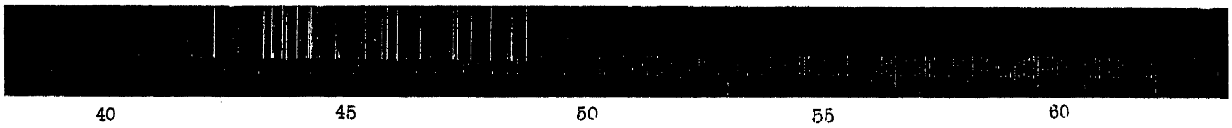
273
Helium *Helium*
Hélium



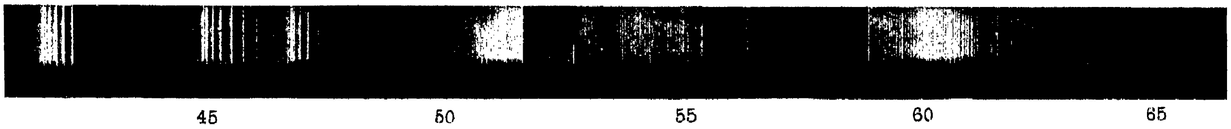
274
Argon *Argon*
d Spectrum *rotes Sp.*
Sp. rouge



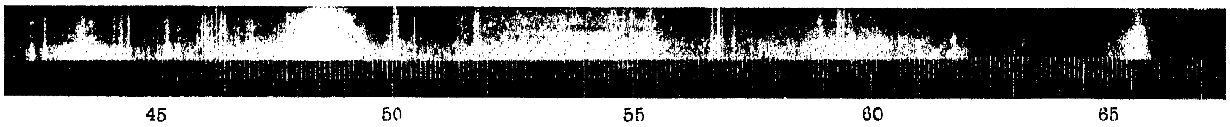
275
Argon *Argon*
e Spectrum *blaues Sp.*
Sp. bleu



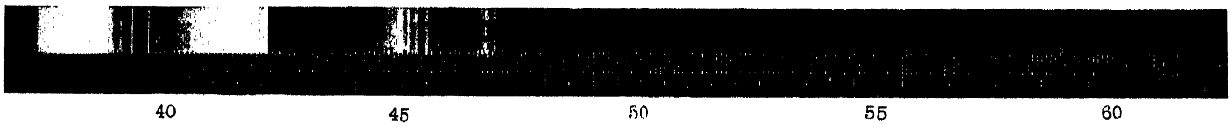
276
Carbon *Kohle*
Arc *Bogen*
Charbon Arc



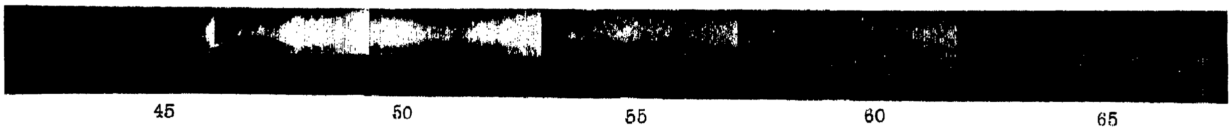
277
Air *Luft*
ne Spectrum *Linien*
Air Lignes



278
Carbon *Kohle*
park with *Funke mit*
lf induction *S. I.*
harbon Étincelle avec S. I.



279
bon Monoxide *Kohlenoxyd*
Oxyde de Carbone



280
Sun *Sonne*
Soleil